IAB- Socioeconomic

FEASIBILITY STUDY

HYDROPOWER DEVELOPMENT LITTLEVILLE LAKE MASSACHUSETTS

United States Army
Corps of Engineers
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New England Division

JAN 83
REVIEW DRAFT

EXECUTIVE SUMMARY

This Feasibility Report documents the investigations of the Littleville Lake Hydropower Study. The purpose of the Littleville Lake Hydropower Study was to determine the feasibility of adding hydroelectric generating facilities to the existing Federal project at Littleville Lake in Huntington and Chester, Massachusetts.

Littleville Dam and Reservoir is a multipurpose flood control and water supply facility. The water supply storage, located between elevations 432 and 518 feet NGVD (National Geodetic Vertical Datum), is for future use by the City of Springfield, as a participant under the provisions of the Water Supply Act of 1958. A normal pool elevation of 518 feet NGVD is maintained at Littleville Lake, except during periods of short duration flood regulation.

All alternatives developed for hydropower generation must be compatible with the authorized purposes of the existing Federal project. Because of this requirement, the alternatives examined in this study would maintain the pool at elevation 518 and would operate as "run of river" projects where outflow is equal to the reservoir inflow as is the current operation of the Littleville Lake facility.

The first alternative examined, the recommended alternative, would utilize the existing City of Springfield water supply intake tower and the 48-inch diameter water supply conduit through the dam. This water supply conduit and an additional 60 feet of steel penstock would be utilized to divert flows to a powerhouse located 200 feet downstream of the toe of the dam. The powerhouse would contain a single horizontal Francis turbine and a synchronous generator with an installed capacity of approximately 800 kilowatts. The plant could generate an average of 2,674,000 kilowatt-hours annually at a cost of 66 mills/kwh. By utilizing power values based on displaced energy analysis, it was determined that the benefit/cost ratio for this alternative would be 2.25 to 1.

The second alternative examined in this study utilizes the existing flood control outlet and requires the construction of a separate 5-foot diameter steel penstock extending from the outlet to a powerhouse located 500 feet downstream of the dam. The powerhouse would contain a single horizontal Francis turbine and a synchronous generator with an installed capacity of approximately 1,000 kilowatts. The plant could generate an average of 2,911,000 kilowatt-hours annually at a cost of 84 mills/kwh. The displaced energy analysis indicates that this alternative has a benefit/cost ratio of 1.78 to 1.

Alternative 1 was selected as the recommended plan based on economic and environmental considerations. The recommended plan generates a greater dollar value of net benefits and therefore causes the greater contribution to the national economy. In environmental considerations the recommended plan benefits both the reservoir and downstream fishery by increasing minimum dissolved oxygen levels during the summer months and creates a year-round cold water fishery downstream in place of the existing seasonal one.

The development of hydropower generating facilities at Littleville Lake would not interfere with the present project purposes and would provide an opportunity to develop a clean, renewable source of energy at a reasonable cost. In light of the escalating price of electricity generated by fossil fuel and the nation's attempt to reduce our dependence on foreign sources of fuel, it was concluded that the development of hydroelectric generating facilities at Littleville Lake would be in the Federal interest. A recommendation was made that the construction of hydroelectric generation facilities at Littleville Lake be authorized.

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SCOPE OF STUDY

This is a Feasibility Report which summarizes the investigations of the Littleville Lake Hydropower Study. The purpose of the Littleville Lake Hydropower Study is to determine the potential of adding hydropower generation to the existing flood control-water supply facility located at Littleville Lake in the communities of Huntington and Chester, Massachusetts. All alternatives developed for hydropower generation must be compatible with the authorized purposes of this Federal project.

STUDY AUTHORITY

The authority for this study is contained in the resolution of the Committee on Public Works of the United States Senate adopted 11 May 1962:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved 12 June 1902, be, and is hereby requested to review the reports of the Connecticut River, Massachusetts, New Hampshire, Vermont and Connecticut published as House Document Numbered 455, Seventy-fifth Congress, second session, and other reports, with a view to determining the advisability of modifying the existing project at the present time, with particular reference to developing a comprehensive plan of improvement for the basin in the interest of flood control, navigation, hydroelectric power development, water supply and other purposes, coordination with related land resources."

EXISTING CONDITIONS

EXISTING FACILITIES

Littleville Dam and Reservoir is located in western Massachusetts on the Middle Branch of the Westfield River, one mile upstream of its confluence with the main stem of the Westfield River in the communities of Huntington and Chester as illustrated in Figure 1. The project was initiated in 1962 and completed in September 1965.

Littleville Dam and Reservoir is a multipurpose flood control and water supply facility. As part of the comprehensive plan for flood protection in the Connecticut River basin, the project contributes to flood reductions at damage centers on the Westfield and Connecticut Rivers. The water supply storage is for future use by the city of Springfield, as a participant under the provisions of the Water Supply Act of 1958.

At spillway crest, Littleville Reservoir has a total storage capacity of 32,400 acre-feet of which 23,000 acre-feet are for flood control. The flood control storage is equivalent to 8.3 inches of runoff from the contributing drainage area of 52.3 square miles. A map of the Westfield watershed is illustrated on Plate A-1 in Appendix A. When filled to spillway crest, the reservoir will extend upstream along the Middle Branch for a distance of approximately 3.7 miles and have a surface area of 510 acres. A 275-acre lake is maintained to enhance public use and recreation at the level of the water supply pool. The project lands lend themselves to recreational use and afford opportunities for fishing and boating. A reservoir map of Littleville Lake is illustrated on Figure 2.

Important physical components at Littleville Lake consist of a rolled earth dam and dike, a chute spillway composed of a concrete weir, two separate outlet works and storage capacity for both flood control and water supply. A general plan and profile of the dam are illustrated on Plates A-2 and A-3 in Appendix A.

The dam embankment consists of rolled earth fill with an impervious core and rock slope protection. The dam is 1,360 feet in length and has a maximum height above streambed of 164 feet. The top of the dam is at elevation 596 feet National Geodetic Vertical Datum of 1929 (NGVD), which was formerly referred to as mean sea level datum. The spillway is at elevation 576 feet NGVD which provides 15 feet of spillway surcharge and 5 feet of freeboard. The dam crest is 25 feet wide and accommodates a paved access road of 18 feet in width. The embankment slope varies from 1 on 3 to 1 on 2.5.

A rolled earth fill dike is located on the left abutment of the dam which closes a natural saddle between the left abutment of the spillway and high ground. The top of the dike is at elevation 596 feet NGVD.

The spillway consists of a concrete ogee weir located on a bedrock plateau on the left bank and a chute type spillway in a bedrock cut. The weir has a length of 400 feet with a crest elevation of 576 feet NGVD, which is 7 feet above the approach channel bottom. The discharge channel width varies from 372 feet at the foot of the curved weir to 50 feet at a distance of 440 feet downstream. The total length of the spillway channel is 1,250 feet, with bottom slopes varying from 5 to 21.5 percent. The excavated approach area has a 1 percent slope towards the reservoir.

The Littleville project has two separate reservoir outlet works, one for water supply releases and the other for flood control releases.

The flood control outlet works consist of an intake channel, gates, tower and outlet tunnel. The 20 foot wide intake channel is excavated in rock to an elevation of 515 feet NGVD. Near the intake structure the channel widens to accommodate a 30 foot concrete weir having a crest elevation of 518 feet which is the bottom of the flood control pool and the top of the water supply pool. From the weir a concrete lined channel extends 88.5 feet to the gate structure. Flows are regulated by two 4 x 8 foot wide sluice gates, and discharged through a 370-foot long, 8-foot diameter concrete-lined "horseshoe" tunnel.

The main components of the water supply outlet works consist of a 17.5 wide intake channel with its invert at elevation 432 feet NGVD, an intake structure consisting of a wet well tower with four 36 inch diameter sluice gates at different elevations so that water can be drawn from various levels, an outlet conduit and a 20-foot wide outlet channel. The outlet consists of a 48 inch diameter concrete conduit installed on a cradle within a 9-foot wide arch shaped conduit 800 feet in length. The outlet was originally used for diversion of the Middle Branch during the construction of Littleville Dam.

ENVIRONMENTAL SETTING

General

The Westfield River Basin is located in Berkshire, Franklin, Hampden and Hampshire Counties in Massachusetts and a small portion of Hartford County in Connecticut as illustrated on Plate 1. The basin has a total drainage area of 517 square miles and is the fifth largest subdrainage of the Connecticut River.

Littleville Dam is located along the Middle Branch of the Westfield River approximately one mile upstream of its confluence with the main stem in the towns of Huntington and Chester (see Plate A-1, Appendix A). The extent of the project area is shown on Plate 2.

Topography

The Westfield River Basin lies within the New England Upland section of the New England physiographic province. The area is generally characterized by steep-sloped, rocky hills that are separated by narrow valleys and drained by many small streams. The topography is primarily bedrock-controlled, although glaciation has extensively modified the pre-existing features.

The Middle Branch of the Westfield River falls 1,100 feet over its 16-mile length at an average gradient of approximately 70 feet per stream mile. Watershed elevations range from 40 feet NGVD at the river's confluence with the Connecticut River to 2,505 feet NGVD at the headwaters of the Westfield River. Elevations near the project area range from 432 feet NGVD upstream of the dam site to 1,296 feet NGVD at the top of Goss Hill.

Geology

The bedrock hills and ridges of the Westfield River Basin are generally blanketed by a thin cover of glacial till, consisting of unsorted material deposited directly by the glacier and ranging in gradation from clay to boulders. The bottoms of most of the main valleys have been deeply filled by deposits of till and outwash. The outwash deposits, which consist of variable, roughly-stratified sand, silt, and gravel, form narrow flood plains along valley bottoms and terraces on the valley walls.

Bedrock outcrops are common through the thin till cover on the upper slopes and tops of the hills. In the valleys, bedrock is exposed only where the rivers have cut through the till and outwash. The bedrock of the region consists of a series of folded Paleozoic crystalline rocks, mostly mica schist, of several formations. The folds generally trend north-south.

Climate

The Westfield River watershed has a cool semihumid climate typical of the New England region. The average annual temperature is about 45 degrees Fahrenheit with monthly averages varying from about 69 degrees in July to about 21 degrees in January. Extremes in temperature range from summertime highs in the nineties to wintertime lows in the minus twenties. The average annual precipitation over the watershed is approximately 46 inches, uniformly distributed throughout the year, generally occurring as periodic storm fronts of 1 to 2 days duration. Much of the winter precipitation occurs as snow with an average annual snowfall of about 56 inches. The snowpack usually reaches a maximum in early March with an average maximum water equivalent of about 4.0 inches.

Water Quality

The 1965 construction of Littleville Dam across the Middle Branch of the Westfield River created a 275-acre lake with an average depth of 54 feet. During nonflood periods the reservoir is normally kept at a target elevation of 518 feet NGVD and contains a volume of approximately 9,400 acre-feet. The City of Springfield owns the water space between elevation 432 feet and 518 feet under a 1967 agreement with the Corps of Engineers. Because of potential use as a public water supply, the reservoir bottom was cleared. Besides input from the Middle Branch of the Westfield River, Littleville Lake also receives inflows from four tributaries, including Winchell Brook, which drain from upland wetlands well above the lake elevation.

The Middle Branch of the Westfield River above Littleville Lake is rated Class A by the Massachusetts Water Resources Commission and as such is designated for use as a public water supply. There are no significant point-source discharges upstream from Littleville Lake and the water quality at the project generally meets the requirements of its Class A designation.

Downstream from Littleville Lake to the confluence with the Westfield River, the Middle Branch is rated Class B, seasonal cold water fishery. The Massachusetts Division of Water Pollution Control has indicated that this section of the Middle Branch has "very high water quality" with little input from pollution sources.

More detailed information concerning water quality can be found in Appendix B - Water Quality Investigations.

Aquatic Ecosystem.

The Littleville Reservoir is a diamictic lake that stratifies during the summer and winter months followed by turnover or mixing in the fall and spring. In general, stratification begins in May and becomes more prominent during June. By July and August, the strata are clearly defined with an upper zone (epilimnion) about 5-10 feet thick, a middle zone (metalimnion) ranging from 10-20 feet in thickness, and a lower zone (hypolimnion) extending 50-70 feet above the bottom. Water temperatures during August generally range from 42-44°F near the bottom and to 78°F at the surface. This stratification causes a decrease in dissolved oxygen (DO) in the hypolimnion by July. Minimum DO values occur in September when values below the 20-25 foot depth are generally less than 5 parts per million (ppm), which is considered stressful for coldwater fish such as trout. The fall turnover usually occurs by October so that the DO levels in the lower stratum are generally above 5 ppm and close to saturation.

Littleville Lake and the Middle Branch upstream of the lake, provide habitat for a variety of cold water and warm water species of fish. Table C-2 found in Appendix C - Environmental Assessment indicates common species collected during recent surveys conducted by the Massachusetts Division of Fisheries and Wildlife (MDFW). Littleville Lake is managed by the MDFW as a "put and take" trout fishery. Approximately 8,000-10,000 9 to 12 inch sized trout are annually stocked. Stocked species mainly consist of rainbow and brown trout, but vary with their annual availability from the state's hatcheries.

The habitat downstream of Littleville Lake was surveyed in 1977 by the MDFW. Species collected included small-mouthed bass, white sucker, fallfish and brown bullhead. This area is occasionally stocked with 2,000 trout during the spring. Although the area does provide suitable trout habitat for most of the year, cold water fishery temperature requirements generally are not met from June 30 to September 15.

The Westfield River was once a migration pathway for Atlantic Salmon. Since the industrial age, degradation of water quality near and below its confluence with the Connecticut River and the installation of 13 dams along the three branches precluded annual spawning runs in this reach of the river.

Terrestrial Ecosystem

Vegetation

Littleville Lake and the surrounding forest comprise approximately 90 percent of the 1,640 acres held in fee at the project. Open woodlands and fields account for 9 percent while the remainder of the property includes flood control structures, operation and maintenance areas, access roads and boat ramps. Table C-3 in Appendix C illustrates the land cover types surrounding Littleville Lake.

Most of the forest is comprised of second growth northern hardwood and hemlock-hardwood cover types. Common hardwood species include American beech, sugar maple, red maple, yellow birch, paper birch, white birch, red oak, American elm and white ash. Dominant softwoods include Eastern hemlock, white pine, and red pine. A variety of common northeastern ferns, shrubs and wildflowers occur in the understory. A detailed discussion of the area's vegetation can be found in Appendix C - Environmental Assessment.

Wildlife

The forest and regenerating fields serve as habitat for a variety of resident and migrating wildlife. White-tailed deer is the only "big game" species in the area. Typical upland species include varying hare, cottontail rabbit, gray squirrel, red squirrel, racoon, ruffed grouse and American woodcock. The woodlands provide food and habitat for a wild turkey population, especially during late winter and spring. Littleville Lake is also used as a resting area for migrating waterfowl. A more detailed description of the area's wildlife can be found in Appendix C - Environmental Assessment.

Rare and Endangered Species

Currently, there are no Federally listed threatened or endangered species residing in the project area. The Commonwealth of Massachusetts has compiled a list of State rare and local species which may or may not occur in the area. These species are not Federally listed as threatened or endangered, nor are they proposed.

The Massachusetts state ornithologist indicates that the area may serve as habitat for the great blue heron (<u>Ardea herodias</u>), the Cooper's hawk (<u>Accipiter cooperii</u>) and the sharp-shinned hawk (<u>Accipiter sciatus</u>). The lake chub (<u>Couesius plumbeus</u>), which only occurs in the Westfield River Basin, is currently designated as a species of "Special Consideration". The Massachusetts Natural Heritage Program has indicated that no rare plants have been presently recorded in the project area.

Recreational Resources

Fishing is the primary recreational activity that takes place on Littleville Lake and along the shore in designated locations. Sport fishing, primarily for trout, accounts for about 39 percent of the total recreational visitation at Littleville Lake, while sightseeing, mostly at the dam accounts for about 52 percent. Most of the shoreline fishing takes place in the vicinity of the two boat launching ramps at the Huntington Access Area near the dam, and at the Dayville Access Area at the upper end of the lake. Over the past six years, sport fishing has averaged approximately 28,000 visitor days annually.

Historic and Archaeological Resources

Few prehistoric sites are reported in the Westfield valley above its confluence with the Connecticut River. The apparent scarcity of sites within the drainage basin is probably due more to the small amount of survey performed to date, rather than a true absence of prehistoric inhabitants. Examination of soil maps coupled with surface examination of the Littleville Lake area reveals that the flood plain terrace of the Middle Branch had high potential for prehistoric occupation. However, most of this terrace is now permanently inundated, and was stripped and grubbed prior to reservoir construction, destroying or rendering inaccessible any sites below elevation 518.

Examination of historic period maps revealed that prior to dam construction, the area contained 2 store sites and over 30 dwelling sites. Unfortunately, dam construction and clearing for the permanent pool obliterated nearly all of these features.

Socioeconomic Resources

Overview

The Westfield River Basin encompasses, either wholly or partially, approximately 30 communities in western Massachusetts. Communities in the northern portion of the watershed are primarily rural and sparsely populated. More concentrated population centers lie in the southern portion of the watershed.

Early development within the basin occurred along the rivers and streams on the eastern slopes of the Berkshires during the mid-1700's. The establishment of grist, saw and paper mills and tanneries characterized early industry. However, due to the rugged terrain throughout the region, expansion of industry was limited to the southeastern portion of the watershed with the northern communities concentrating on agricultural activities.

Population

Holyoke, with a population of 44,678 in 1980, is the most populated community in the watershed, followed by Westfield with 36,465, West Springfield with 27,042 and Agawam with 26,271. All other communities with the exception of Tolland and Southfield in Connecticut and Southampton in Massachusetts have populations under 2,000. Huntington, where Littleville Dam lies, had a 1980 population of 1,804 and Chester, where the impoundment area is located, had a 1980 population of 1,123. More information on the populations of these communities is provided in Table C-4 in Appendix C.

Employment

Chester's labor force averaged 465 in 1981. With 34 people unemployed, the community had an unemployment rate of 7.3 percent. Huntington's labor force of 657 fared better with an unemployment rate of 6.8 percent. These rates, however, exceeded the State's rate of 6.4 percent in 1981. More detailed labor force data can be found in Table C-5 in Appendix C.

HYDROLOGIC CHARACTERISTICS

Watershed

The Westfield River watershed covers a large portion of the eastern slopes of the Berkshires in western Massachusetts and has a total drainage area of 517 square miles. Topography of the upper portion of the Westfield River basin is rough and rocky and is drained by many small streams which are conducive to rapid runoff.

The Westfield River has three principal headwater tributaries: the main stem Westfield, Middle Branch and West Branch. Littleville Dam is located on the Middle Branch of the Westfield River, approximately 1 mile upstream of its confluence with the main river. The Middle Branch originates near the Peru-Worthington town line in northwest Worthington and flows in a southeasterly direction for about 16 miles to its confluence with the Westfield River at Goss Heights in Huntington. It has a drainage area of about 53 square miles. A more detailed description of the watershed can be found in Appendix A - Hydrologic Analysis.

Streamflow

The average annual streamflow in the Westfield basin is about 55 percent of the mean annual precipitation, or 25.7 inches of runoff, equivalent to an average runoff rate of about 2 cfs per square mile of watershed area. Based on 61 years of streamflow records on the Westfield River at Westfield, Massachusetts, the maximum annual runoff was 44.1 inches in 1928 and the minimum annual runoff was 11.1 inches in 1965. Though precipitation is quite uniformly distributed throughout the year, the melting of the winter snow cover results in about 50 percent of the annual runoff during the months of March, April and May. Flows are usually lowest during the months of July, August and September.

The USGS gaging station 01180500 at Goss Heights, Massachusetts is located on the Middle Branch just downstream of Littleville Dam. The gage has recorded flows from its 52.6 square mile drainage area since 1911. As water supply diversions from Littleville Lake have not yet commenced and because the principal operation is for short term flood control, the monthly flows, recorded at the downstream gaging station, at Goss Heights, are considered representative of the natural monthly flows at Littleville. A summary of average, maximum and minimum monthly flows, recorded at Goss Heights are listed in Table A-2. An average annual flow duration curve (discharge rate versus percent of time) is shown on Plate A-5 and individual monthly flow duration curves, used to calculate monthly potential energy, are shown on Plates A-6 through A-9. All the above tables and plates can be found in Appendix A - Hydrologic Analysis.

Reservoir Storage

Littleville Reservoir has a total storage capacity of 32,400 acre-feet between invert elevation 432 and spillway crest 576 feet NGVD. Of the total storage, 9,400 acre-feet, between elevations 432 and 518 feet NGVD, is owned by the city of Springfield, Massachusetts and is used as a backup to their domestic water supply system. This 9,400 acre-feet is equivalent to about 3.4 inches of runoff from the contributing 42.3 square mile watershed area above Littleville Dam. The remaining 23,000 acre-feet is for flood control storage and is equivalent to 8.3 inches of runoff from the contributing watershed area. The normal pool elevation at Littleville Dam is elevation 518 feet NGVD, except during periods of short duration flood regulation. Pertinent data on storages and elevations at Littleville is listed in Table A-3 and a storage-capacity curve is shown on Plate A-10, both in Appendix A.

Water Supply

As mentioned previously, the 9,400 acre-feet of storage at Littleville Lake, between elevations 432 and 518 feet NGVD, is owned by the city of Springfield as a backup to their water supply system. Water supply diversions from Littleville would be made through a 48-inch diameter water supply pipeline which would convey flow through the Huntington pump station into the Cobble Mountain reservoir on the Little River. Cobble Mountain reservoir has a drainage area of 48.5 square miles with a total capacity of about 70,000 acre-feet and is the principal water supply source for the city of Springfield. Present demand on the Springfield water supply system is about 37 million gallons per day (MGD) with little change since 1959 as can be seen in Table A-4, Appendix A. The existing Springfield system has a dependable yield of about 44 MGD exclusive of Littleville, and with diversions from Littleville the dependable yield could be as high as 70 MGD. The city of Springfield also owns Ludlow reservoir which the City believes has a yield of 5-7 MGD and could be utilized in emergency situations. Since the completion of Littleville Dam in 1965, water supply diversions have not been required. A discussion of the effects of water supply diversions on hydropower potential is located in Appendix A.

Minimum Releases

Minimum releases from Littleville are generally that of the natural streamflow less evaporation losses. A minimum release of about 10 to 20 cfs is usually maintained at Littleville Dam during periods of flood control regulation in order to sustain downstream fish life. In addition, Section 10 in Chapter 628 of the Acts and Resolves of the Commonwealth of Massachusetts, authorizes the Massachusetts Water Resources Commission to fix and regulate low flow requirements from Littleville Lake after water supply diversions have been initiated. The Commission established a minimum flow of 5 cfs in 1969.

PROPOSED ALTERNATIVES

HYDROPOWER POTENTIAL

The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. This gravitational potential energy is transformed into mechanical energy by turning a turbine which in turn creates electrical energy by turning a generator. The potential rate of power generation is normally measured in kilowatts. The potential amount of power generation over a period of time, "energy" is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream, river or lake is a function of the average annual streamflow and the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate, therefore, it is the magnitude of these two quantities and their variability that determines the potential energy of a site and its dependability.

Because of the seasonally low flow character of the Middle Branch of the Westfield River and the lack of hydropower storage for monthly or seasonal storage regulation, any hydropower development at Littleville was formulated and evaluated as a "run-of-river" operation where outflow available for generation is equal to inflow to the Lake. The hydropower pool would remain at the 518 elevation currently maintained. Though capacity would not be dependable, it is noted that with a permanent hydropower pool at elevation 518, the capability of providing "spinning reserve" capacity for emergency short term generation would exist.

At Littleville Dam with the normal pool elevation of 518 feet NGVD and a tailwater elevation of about 425 feet, a gross hydraulic head of 93 feet exists. Net power head was computed by subtracting hydraulic losses from the gross head under varying operating discharges for each alternative. The overall plant efficiency is the turbine efficiency times the generator efficiency. Turbine efficiency was assumed to vary throughout the anticipated hydraulic operating range, in accordance with the turbine performance curves shown on Plate A-11 in Appendix A. Turbine efficiency was considered equal to 88 percent at rated capacity and generator efficiency was considered to be constant at 95 percent throughout its operating load range.

ALTERNATIVE 1

This alternative utlizes the existing City of Springfield water supply intake tower and the 48 inch diameter water supply conduit through the dam, as shown in Plate 3. This water supply conduit and an additional 60 feet of steel penstock would be utilized to divert the flows to the proposed powerhouse located 200 feet downstream of the toe of the dam. This powerhouse would contain a single horizontal Francis turbine and a synchronous generator with an installed capacity of approximately 800 kilowatts (kw). The plant would have a minimum net head of 79 feet and is capable of generating on an average, 2,674 megawatt hours (mwh) of energy annually. The design discharge of this alternative is 125 cfs and generation would occur with flows between 82 cfs and 140 cfs. Whenever inflow to the reservoir is less than 82 cfs, generation would cease and discharge of flows will occur utilizing a 36 inch bypass conduit through the powerhouse. Flows in excess of the turbine overload capacity of 140 cfs would be passed through the flood control outlet. Pertinent data on this alternative can be found in Table 1. Typical sketches of Alternative 1 can be found on Plates 4 and 5.

TABLE 1

PERTINENT DATA-ALTERNATIVE 1

Turbine Type	Horizontal Francis
Turbine Size	28 inches (712 mm)
Rated Head	82 feet
Design Flow	125 cfs
Head Range	79-88 feet
Flow Range	82-140 cfs
Generator Type	Synchronous
Generator Capacity	800 kw
Potential Energy Generation	2,674,000 kwh
Plant Factor	0.38

As previously mentioned, the water supply intake tower will be used to divert water for hydropower operation in this alternative. This tower has four 3 foot diameter intake portals located at elevations 447, 465, 483.8 and 502.2 feet NGVD. Flow requirements for hydropower operation require the use of two portals during times of generation. By withdrawing water from various elevations in the lake it is possible to create a year round cold water fishery downstream of the reservoir. A detailed discussion of the effects of the multi-level withdrawals and its effects on both the reservoir and the river downstream can be found in Appendix B - Water Quality Evaluation and Appendix C - Environmental Assessment. The existing screens located in the intake tower will serve as the trash rack for the unit.

ALTERNATIVE 2

Alternative 2 utilizes the existing flood control outlet as shown on Plate 6, and requires the construction of a separate 5-foot diameter steel penstock extending from the outlet works to a powerhouse located approximately 500 feet downstream of the toe of the dam. The powerhouse would contain a single horizontal Francis turbine and a synchronous generator with an installed capacity of approximately 1,000 kw. The plant would have a minimum net head of   feet and is capable of generating, on the average, 2,911 mwh of energy annually. The design discharge of this alternative is 160 cfs and generation would occur with flows between   cfs and   cfs. Whenever inflow to the reservoir is less than   cfs, generation would cease and discharge of flows would occur utilizing the flood control outlet. Pertinent data on this alternative can be found in Table 2. Typical sketches of Alternative 2 can be found on Plates 6, 7 and 8.

TABLE 2

PERTINENT DATA-ALTERNATIVE 2

Turbine Type	Horizontal Francis
Turbine Size	31.5 inches
Rated Head	86 feet
Design Flow	160 cfs
Head Range	
Flow Range	
Generator Type	Synchronous
Generator Capacity	1,000 kw
Potential Energy Generation	2,911,000 kw
Plant Factor	0.33

POTENTIAL ADDITIONAL ALTERNATIVE FEATURES

Low Flow Augmentation

As previously mentioned, the City of Springfield owns the rights to the water stored in the reservoir between elevations 432 and 518 feet NGVD. The City considers Littleville Lake as a backup source of water for their water supply system and have not ~~required~~ to use Littleville since the facility was constructed. Therefore, ~~during this time~~ a pool is maintained at elevation 518 feet and outflow from the lake ~~is~~ generally that of the natural streamflow into the lake less evaporation losses. During periods of flood control operation, a minimum release of 10 to 20 cfs is maintained to sustain downstream fish life. The Massachusetts Water Resources Commission, which is authorized by statute to regulate minimum flow after water supply diversions are initiated, require a minimum downstream release of 5 cfs during water supply operations.

The United States Fish and Wildlife Service (FWS) requested the New England Division investigate the possibility of providing a minimum flow of 10 cfs downstream as a feature of hydropower alternatives. By temporarily raising the pool to elevation 520 feet NGVD, a minimum downstream flow of 10 cfs can be maintained during low flow periods (June-August) during water supply operations without affecting the City of Springfield's storage. This additional water would not have a negative impact on hydropower alternatives.

COST ESTIMATES OF ALTERNATIVES

Cost estimates for each alternative have been prepared using standard engineering practices. Estimates of construction costs including contingencies at September 1982 price levels are presented in Table 3.

For this report hydropower additions at Littleville Lake are assumed to have an economic life of 50 years. Currently, as prescribed by law, Federal agencies use a 7-7/8 percent interest rate to determine economic feasibility. Construction time for either alternative is expected to be approximately 18 months and interest during construction (IDC) is included in the cost estimates. The cost of operation and maintenance is estimated by multiplying the total construction cost by 2 percent. This operation and maintenance fund would allow replacement of miscellaneous equipment and facilities that wear out during the life of the project. The total investment costs and annual costs for both alternatives are shown on Table 4.

TABLE 3

ESTIMATED CONSTRUCTION COSTS

Item	Alternative 1	Alternative 2
Access & Site Preparation	$ 53,000	$ 76,000
Environmental Controls	14,000	14,000
Powerhouse	62,700	70,000
Tailrace	5,300	6,000
Station Electric Equipment	170,000	178,000
Miscellaneous Mechanical Equipment	55,000	60,000
Switchyard Equipment	69,000	70,000
Transmission Lines	48,000	51,000
Turbine & Generator	660,000	740,000
Penstock	33,000	310,000
Intake Trash Rack	-	1,000
Gates and Valves	20,000	74,000
Control of Water	10,000	30,000
Subtotal	$1,200,000	$1,680,000
Contingencies (20%)	240,000	336,000
Total Construction Cost	$1,440,000	$2,016,000

TABLE 4

ANNUAL COST FOR ALTERNATIVES

Item	Alternative 1	Alternative 2
Total Construction Cost	$1,440,000	$2,016,000
E&D/S&A (17.5%)	252,000	353,000
Total Project Cost	$1,692,000	$2,369,000
Interest During Construction	118,000	161,000
Total Investment Costs	$1,810,000	$2,530,000
Interest & Amortization	146,000	204,000
Operation & Maintenance (2%±)	30,000	40,000
Total Annual Cost	176,000	244,000
Average Annual Energy Produced (kwh)	2,674,000	2,911,000
Energy Production Costs (mills/kwh)	66	84

ALTERNATIVE EVALUATION

ECONOMIC ANALYSIS

The purpose of this section is to estimate the economic benefits and determine the economic feasibility of certain hydropower additions to the existing flood control/water supply facility at Littleville Lake.

The conceptual basis for evaluating the benefit from energy produced by hydropower plants is society's willingness to pay for these outputs. It is a universally accepted economic concept that society is best served in making resource allocation decisions by pricing output equal to marginal costs. However, historically there have been difficulties in applying this concept to the electric utility sector due to differing interpretations and various estimation methods. Recognizing the interest in the development of small hydropower throughout the nation and realizing that a value must be assigned to its output, Congress passed "The Public Utility Regulatory Policies Act of 1978" (PURPA), effective March 20, 1980. The rules of this Act require utilities to purchase energy and capacity from small-scale hydro plants (under 80 megawatts) using the concept of "marginal" or "avoided" or "incremental" costs. The authority for setting the rates at which small hydropower output will be purchased rests with each State and its appropriate public utility commissions. The Commonwealth of Massachusetts has not yet set its PURPA rates, so the Federal Energy Regulatory Commission (New York Office) was asked to place a value on the power to be produced by each alternative under consideration at Littleville. FERC accomplished this task using the following three methods: (i) estimate the resource cost of the most likely thermal alternative to be implemented in the absence of hydropower development, (ii) perform a "life-cycle cost" analysis for the most likely alternative in which projected fuel cost increases over the project life are factored into the total resource cost and (iii) measure the "displaced" or "avoided" energy cost that the hydropower addition will accomplish in the existing electrical generation system.

Energy benefits were evaluated for both alternatives over the 50-year period of analysis with the basic assumption that the water supply pool will be maintained at elevation 518 feet NGVD and that no encroachment will be made on flood control storage. Withdrawal of water for water supply purposes could lower the pool below elevation 518 and reduce the hydropower potential and therefore lower the amount of average annual energy produced at the site. An approximate relationship between hydropower potential, installed capacity and system water supply yield is discussed in Appendix A - Hydrologic Analysis.

Most Likely Alternative

FERC has assumed that the most likely alternative to a hydropower addition at Littleville would be a cycling coal-fired steam plant. Oil-fired combined cycle plants are no longer considered a viable alternative due to the high cost of oil, the uncertainty of the world oil situation, national efforts to reduce our dependence on foreign oil supplies and the absence of this type of generation from utility expansion plans. The resource cost of the cycling coal plant is composed of two components, the capacity cost and the energy cost. The measure of the value of the hydropower project's generating capacity is the total of the coal plant's amortized investment cost, transmission cost, interim replacement costs and fixed operating and maintenance costs. The measure of the value of the hydropower project's energy production is the total of the coal plant's variable operation and maintenance costs and fuel costs. The two alternatives at Littleville have capacity factors of 38 percent and 33 percent, respectively, which places their annual generation in the intermediate band on the market load curve. FERC criteria for the ranges of generation are: peaking power - annual capacity factors up to and including 17 percent which corresponds to 1,500 hours of annual operation; intermediate power - annual capacity factors over 17 percent and up to 40 percent which corresponds to 3,500 hours of annual operation and base load - greater than 40 percent capacity factor. Power values estimated under this methodology are found in Table 5.

TABLE 5

POWER VALUES - MOST LIKELY ALTERNATIVE

	Alternative 1		Alternative 2	
Power Value	At-Market	At-Site	At-Market	At-Site
Capacity ($/kw-yr.)	132	123	132	124
Energy (Mills/Kwh)	32	32	28	28

Life Cycle Cost

The measure of the benefit to the hydropower plant in terms of the energy value is predominantly affected by the cost of the fuel consumed by the thermal alternative. The determination of fuel costs is therefore critical in the evaluation of hydropower as they control a significant portion of the benefits. The Principles and Guidelines (ER 1105-2-40, Section 713.615 (a)(1)(ii)) specifically require evaluation of real escalation in fuel prices when the alternative to hydropower is a thermal plant. The cost of fuel for the most likely alternative to Littleville, the coal plant, was estimated to be $2.40 per million Btu based on a recent survey of utilities in the New England Power Pool. Fuel price projections used in the life cycle cost analysis were Department of Energy estimates which were published in the Federal Register of November 1981. These projected rates represent fuel price increases that are over and above the general rate of inflation in the economy. The estimated on-line date for the Littleville hydropower project is 1987 and life cycle cost energy values are based on levelized energy costs over the project life beginning with this date. Since DOE fuel price projections are estimated only to the year 2006, fuel costs were escalated from 1982 to 2006 and then assumed to increase at the general rate of inflation for the remainder of the project life. All energy costs were discounted to 1987 to obtain their present worth then converted to a uniform annual value through application of a capital recovery factor. The power values based on life cycle cost analysis are presented in Table 6.

TABLE 6

POWER VALUES - LIFE CYCLE COST ANALYSIS FOR MOST LIKELY ALTERNATIVE

Power Value	Alternative 1 At-Market	Alternative 1 At-Site	Alternative 2 At-Market	Alternative 2 At-Site
Energy (Mills/Kwh)	43	42	38	37

Displaced Energy Analysis

This method estimates the cost of the energy that the hydropower addition at Littleville will displace from the existing generation system. It is especially applicable in cases where the hydropower addition is small in scale, with no dependable capacity, and it is evident that a thermal alternative will not be built in the absence of construction of the hydroplant. In simple terms the benefit under this method is the difference in system costs incurred by a utility (system) to meet a specific demand without the Littleville hydropower addition compared to the cost the utility would incur with the Littleville hydropower plant meeting part of the demand and the balance supplied by other facilities. To accomplish this, a life cycle cost analysis was performed on the energy displaced by Littleville year-by-year beginning with 1987, the project on-line date. In this analysis, the projected real price increases of fuel oil were utilized since oil-fired generation would be displaced by the hydropower plant. The annual load-duration curves for New England were synthesized from data supplied by NEPLAN (the planning arm of the New England Power Pool) for 1981 and future load projections from the Northeast Power Coordinating Council (NPCC). The type of generation displaced was then taken from capacity band stackings which were put into the annual load duration curve. Projections of capacity changes were also taken from the NPCC reliability report. These provide information through the year 2002. After year 2002 it was assumed that there would be no further change in generation mix and thus in types of generation displaced. The displaced energy method appears to be the most appropriate for the evaluation of hydropower additions at Littleville due to factors of small installed capacity and lack of dependable capacity. The power values based on the displaced energy analysis are illustrated in Table 7.

TABLE 7

POWER VALUES - BASED ON DISPLACED ENERGY ANALYSIS

Power Value	Alternative 1 At-Market	Alternative 1 At-Site	Alternative 2 At-Market	Alternative 2 At-Site
Energy (Mills/Kwh)	148	133	149	135

Determination of Economic Feasibility

The economic feasibility or justification of the proposed hydropower alternatives at Littleville Lake is determined by comparing the annual benefits with the annual costs. The resulting benefit/cost ratio must be

1.0 or greater for an alternative to be considered economically justified and eligible for Federal participation. The annual benefits for each alternative are derived by multiplying the annual energy output by the unit energy value which is a measure of displaced energy cost in the New England Power Pool. Since transmission facilities were estimated as part of the project costs the energy value at market has been used in the Summary of Economic Analysis shown in Table 8.

TABLE 8

SUMMARY OF ECONOMIC ANALYSIS

	Alternative 1	Alternative 2
Installed Capacity	800 Kw	1,000 Kw
Capacity Factor	38%	33%
Average Annual Energy Output	2,674,000 Kwh	2,911,000 Kwh
Energy Value (At-Market)	148 mills/Kwh	149 mills/Kwh
Annual Benefits (At-Market)	$395,700	$433,700
Annual Costs (At-Market)	$176,000	$244,000
Benefit/Cost Ratio	2.25 to 1	1.78 to 1
Net Benefits	$219,700	$189,700

The benefit/cost ratio for each alternative is above unity which demonstrates economic justification.

ENVIRONMENTAL ASSESSMENT OF HYDROPOWER DEVELOPMENT

General

The following sections are summaries of more detailed analyses performed to assess the environmental consequences of hydropower development at Littleville Lake. The New England Division performed a modeling study to delineate changes in water quality associated with each alternative and to aid in the assessment of impacts to the existing fishery. The entire water quality analysis is presented in Appendix B - Water Quality Investigation. A detailed examination of the existing environmental conditions and the potential impacts or consequences of hydropower development has also been analyzed and presented in detail as Appendix C - Environmental Assessment.

Topography, Geology and Climatology

The addition of hydroelectric facilities at Littleville Lake is not expected to have any significant impacts on the topography, geology and climatology of the area because no change in the existing reservoir is proposed. Although construction of the penstocks and powerhouse downstream of the dam would require removal of surface materials immediately downstream of the dam, this activity would have little effect on the natural topography and geology of the site since both were altered during dam construction.

Water Quality

Alternative 1

This alternative utilizes the multilevel port water supply tower which can be used to selectively withdraw water from four different elevations in the reservoir. Withdrawals during the summer density stratification of the lake would change the water quality parameters in the reservoir as well as downstream of the dam. Selective multilevel withdrawal from the reservoir can be managed to optimize downstream water quality conditions for specific fishery management objectives. Use of the water supply tower provides such an opportunity to develop a year round cold water fishery in place of the existing seasonal one.

The multilevel withdrawal would increase hypolimnion and metalimnion temperatures in the reservoir as much as 15° to 20°F above the existing temperatures. The increased mixing of the hypolimnion due to the withdrawal would increase the dissolved oxygen (DO) concentration in this deepest density layer. Under present conditions, DO levels below the epilimnion are generally 5 mg/l or less and may reach as low as 1 mg/l or less during August and September. The increased mixing expected by the alternative would reduce the biological and chemical oxygen demanding substances in the hypolimnion so that the minimum DO levels would be about 4 mg/l.

Construction activities will cause an introduction of suspended and dissolved solids into the downstream section of the river. These increases would only occur during the construction period and mitigation measures to minimize siltation would be implemented during construction, therefore significant impact to downstream water quality is not anticipated.

Alternative 2

This alternative would utilize the existing flood control outlet to divert water to the proposed penstock and powerhouse. Water would be withdrawn at the 518 foot elevation as is the present operation. Therefore, the reservoir and downstream water quality, in terms of temperature, dissolved oxygen (DO) and other chemical parameters would not deviate from existing conditions.

The construction period would cause the same impacts as outlined in Alternative 1 but like the Alternative 1 impacts, they are not considered to cause a significant impact.

Fisheries

Alternative 1

As previously mentioned the most significant change in the reservoir aquatic habitat is the alteration of the summer temperature profiles. This alteration will cause a loss in volume of cold water fishery habitat. A withdrawal from the two lower water supply ports would cause a loss of about

2,300 acre-feet of cold water habitat but by withdrawing water from the top and lower ports during August could reduce this loss by 600 acre-feet.

Hypolimnion withdrawals would benefit both the reservoir and the downstream fishery. The reservoir fishery would benefit due to increases in the dissolved oxygen levels below the epilimnion. The withdrawals would create a downstream year round cold water fishery in place of the seasonal one.

Fish stocked in the reservoir, that are not harvested by anglers, might find their way downstream through the outlet works. The majority of fish would be expected to pass through to the penstock, turbine and tailwaters. Studies indicate that under worst case conditions about 15 percent of the fish that pass through the turbines would probably not survive. Because the significant fishery in the reservoir is a stocked population, the impact is considered a recreational impact rather than an ecological one.

Alternative 2

Since this alternative operates essentially the same as present operation at the reservoir, there would be little impact on the existing reservoir and downstream fishery habitats. With no change in the existing downstream water temperature regime, the cold water fishery would remain seasonal. The reservoir would continue to experience lack of DO at depths during the summer and therefore its value as a cold water fishery habitat is reduced. Turbine mortality would be similar to conditions discussed in Alternative 1.

Terrestrial Ecosystem

Construction of the penstock and powerhouse downstream of the dam in either alternative would involve the disturbance of the grassy habitat that was created during the dam's construction. Once construction is complete, a small portion of this habitat would be permanently replaced by new structures. This loss of habitat is small and not considered to be significant.

Because the existing reservoir pool elevation would not be changed, use of either Alternative 1 or 2 would have little or no impact on the shoreline terrestrial habitat or biota.

Archaeological/Historic

Modifications to the dam will not affect archaeological or historic resources since the area in the immediate vicinity of the dam was heavily disturbed at the time of construction.

Socioeconomic

Since the development of hydropower at Littleville would not interfere with the present project purposes, there are no long term socioeconomic consequences of the development. There would, however, be some short term construction related impacts. These would include the movement of trucks, materials and other equipment into the project area. There would be an increase in air and noise pollution levels during the construction period. These impacts would not be significant since they would be temporary and the construction site is a fairly isolated locale.

SELECTION OF RECOMMENDED PLAN

The recommended plan for development of hydropower facilities at Littleville Lake is Alternative 1. This plan would utilize the multilevel port water supply intake tower and the existing 48 inch diameter water supply conduit to divert water to a powerhouse located approximately 200 feet downstream of the toe of the dam. The powerhouse would contain a single horizontal Francis turbine and a synchronous generator with an installed capcacity of approximately 800 kilowatts. The plant would have a minimum net head of 79 feet and is capable of generating on the average 2,674,000 kilowatt-hours of energy annually.

The project would operate strictly as a "run of river" operation and would maintain the existing pool elevation of 518 feet NGVD. Hydropower operations would utilize flows between 82 and 140 cfs. When flows are below 82 cfs, hydropower generation would cease and flow would be diverted through the powerhouse with a 36 inch diameter bypass conduit. Flows in exess of 140 cfs would be diverted through the flood control outlet as is the current operation.

Alternative 1 was selected as the recommended plan after detailed analysis of economic and environmental investigations conducted for this study.

Both alternatives examined had benefit/cost ratios greater than unity which demonstrates economic justification. The benefit/cost ratios for Alternatives 1 and 2 were 2.25 to 1 and 1.78 to 1, respectively. In cases where more than one plan is economically justified, the criteria for selection, on the basis of economic efficiency, is the plan that maximizes net benefits. Net benefits are the excess benefits that remain after total annual costs are subtracted from the total annual benefits. The plan that generates the greatest dollar value of net benefits therefore causes the greatest contribution to the national economy. The recommended plan, with net benefits of $219,700 creates a greater beneficial economic impact than Alternative 2 with $189,700 in net benefits.

In environmental considerations, Alternative 2 does not alter the existing conditions. The selected plan benefits both the reservoir and downstream fishery by increasing minimum DO levels during summer months and creating a year round cold water fishery downstream in place of the existing seasonal one.

CONCLUSIONS

During the course of this study, two alternatives to add hydroelectric generating facilities to the existing Corps flood control/water supply project at Littleville Lake have been considered. Evaluation of these alternatives indicate that hydroelectric development is not only technically feasible but also economically justified.

The recommended plan, Alternative 1, would locate a powerhouse approximately 200 feet downstream of the dam. Flows would be passed through the existing 48 inch diameter water supply line then discharged to the Middle Branch of the Westfield River. The powerhouse would contain a single horizontal Francis turbine with a 800 Kw synchronous generator that could produce 2,674,000 Kwh of energy annually. The total investment cost for this alternative is $1,810,000 and would provide energy at a cost of 66 mills per kilowatt-hour. The project has a benefit/cost ratio of 2.25 to 1 and has the added feature of enhancing the reservoir fishery and creating a year round cold water fishery habitat downstream.

Alternative 2, which utilizes the flood control outlet, requires an investment cost of $2,530,000 and produces energy at a cost of 84 mills per kilowatt hours. Although the benefit/cost ratio of Alternative 2 exceeds unity (1.78 to 1), the selected plan has $30,000 more net benefits annually than Alternative 2.

The development of hydropower generating facilities at Littleville Lake would not interfere with the present project purposes and would provide an opportunity to develop a clean, renewable source of energy at a reasonable cost. In light of the escalating price of electricity generated by fossil fuel and the nation's attempt to reduce our dependence on foreign sources of fuel, it is concluded that the development of hydroelectric generation facilities at Littleville Lake would be in the Federal interest.

RECOMMENDATIONS

The Division Engineer recommends that the construction of a hydropower facility at the Littleville Lake project in Huntington, Massachusetts is authorized for hydroelectric power generation as described in this Report, with such modifications as in the discretion of the Chief of Engineers may be advisable, at a total project first cost currently estimated at $1,810,000.

The Division Engineer further recommends that the electric power generated at Littleville Lake be delivered to the Department of Energy for transmittal and disposal of such power and energy in such manner as to encourage the most widespread use thereof at the lowest possible rates to consumers consistent with sound business principals as stipulated in Public Law 534.

ACKNOWLEDGEMENTS

The New England Division (NED), U.S. Army Corps of Engineers prepared this report under the overall direction of Colonel Carl B. Sciple, Division Engineer and Joseph L. Ignazio, Chief of the Planning Division. The Basin Management Branch (BMB) of the Planning Division has overall responsibility for the study under the supervision of its Chief, William F. McCarthy. Study management is provided by the Urban Studies Section (USS) headed by John T. Smith.

Study team members include:

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Robert Heald - Operational Concerns

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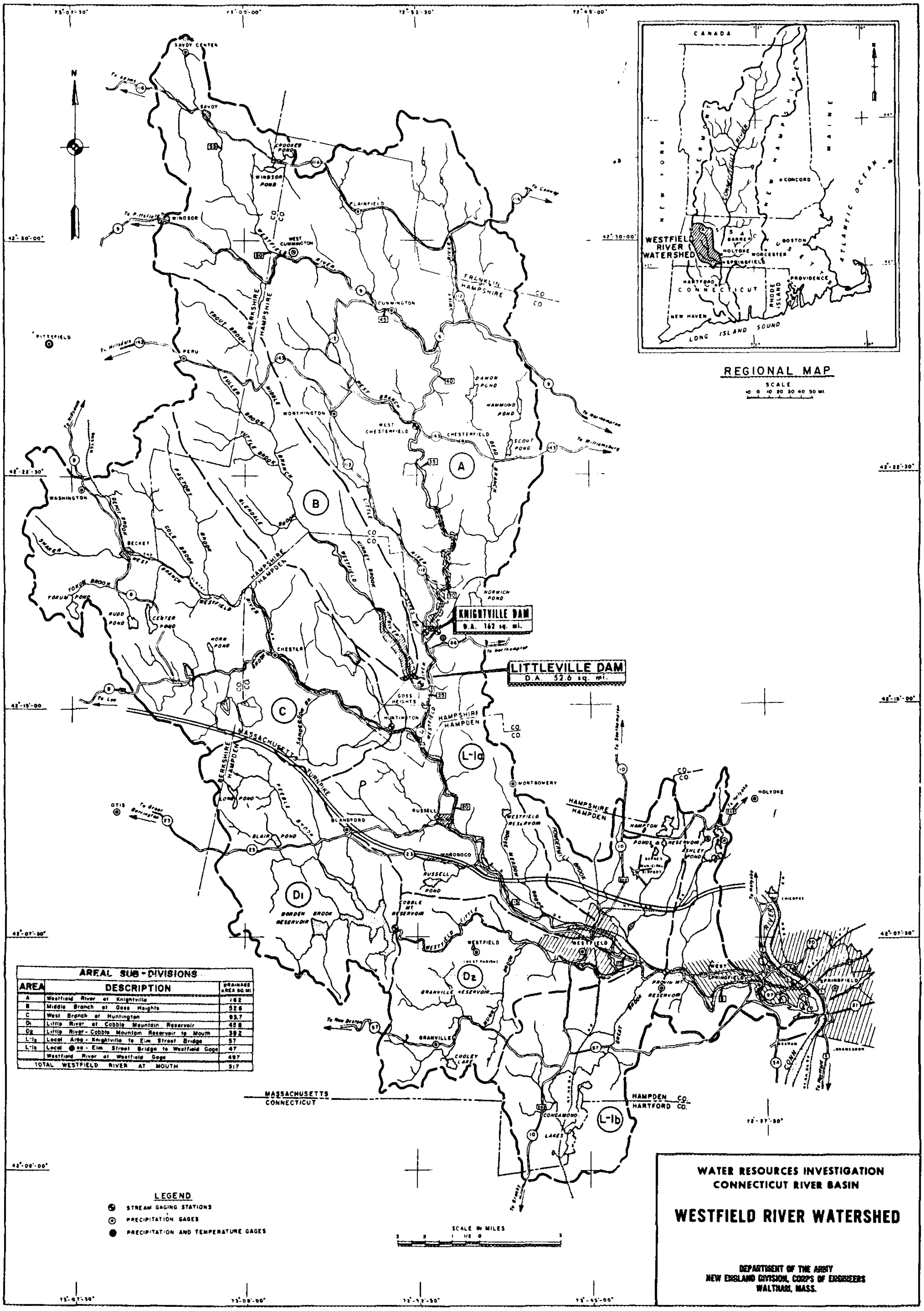


AREAL SUB-DIVISIONS		
AREA	DESCRIPTION	DRAINAGE AREA SQ. MI.
A	Westfield River at Knightville	162
B	Middle Branch at Goss Heights	52.6
C	West Branch at Huntington	93.7
D1	Little River at Cobble Mountain Reservoir	45.8
D2	Little River - Cobble Mountain Reservoir to Mouth	39.2
L-1a	Local Area - Knightville to Elm Street Bridge	57
L-1b	Local Area - Elm Street Bridge to Westfield Gage	47
	Westfield River at Westfield Gage	497
TOTAL WESTFIELD RIVER AT MOUTH		517

PLATE 1

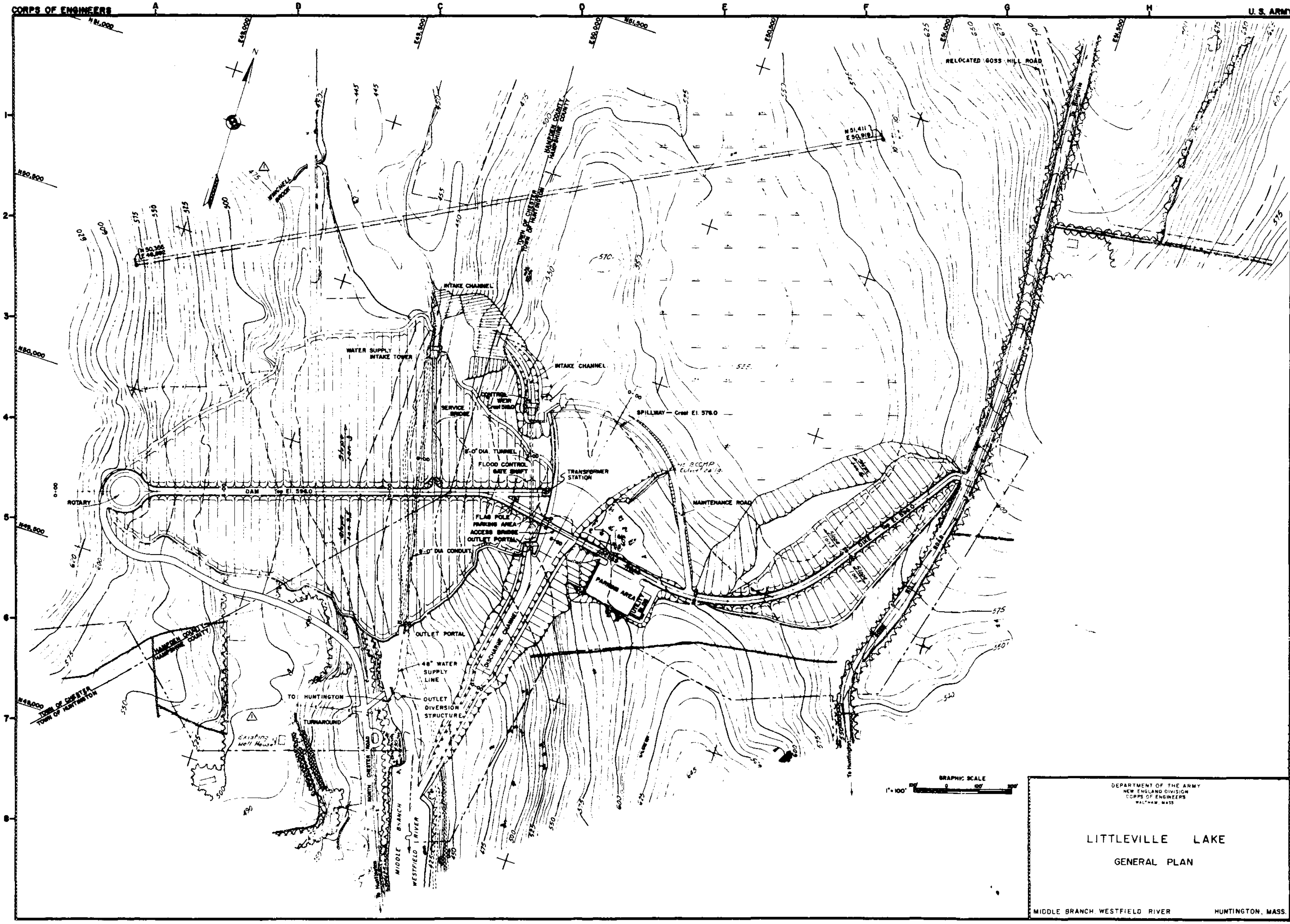
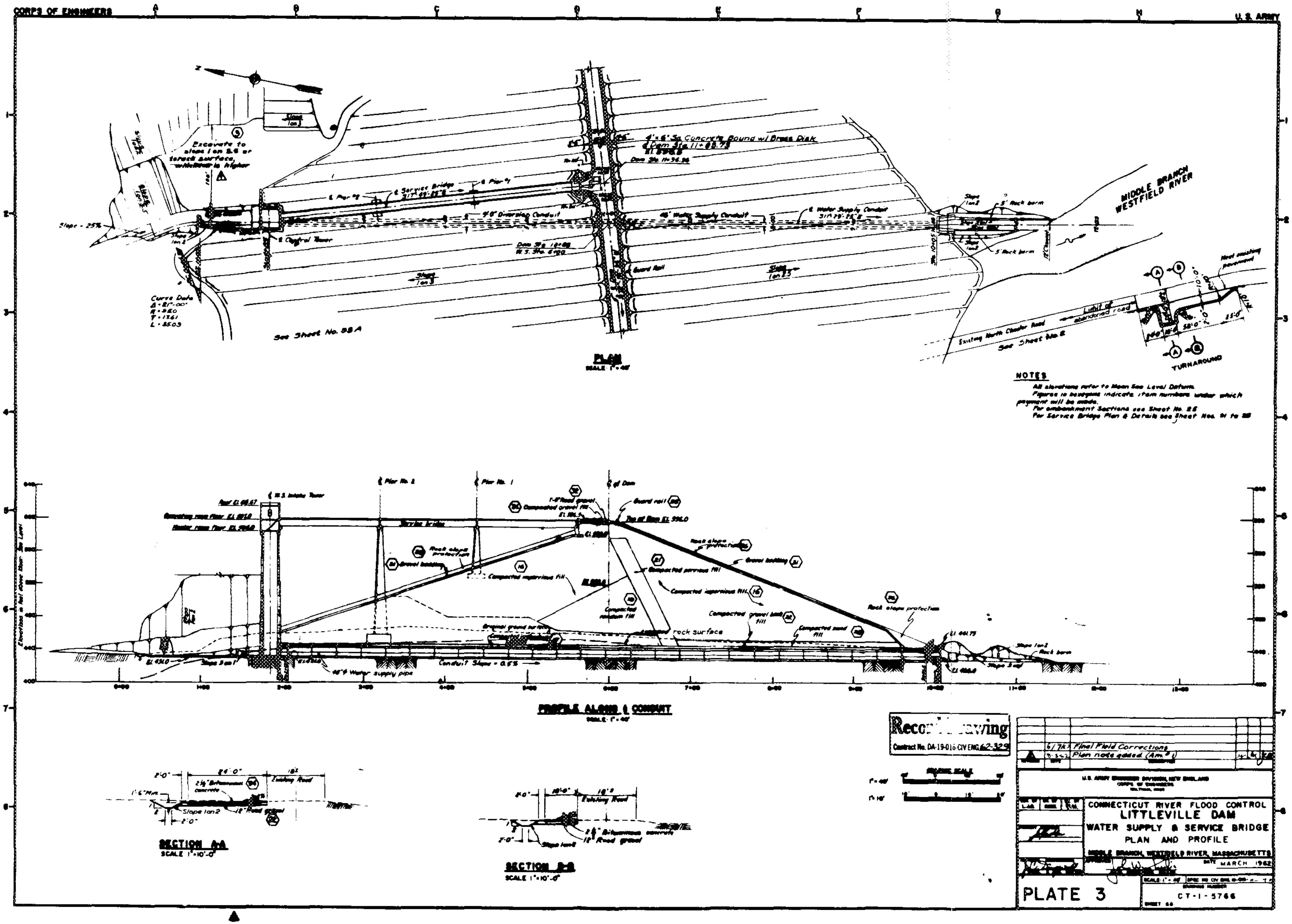
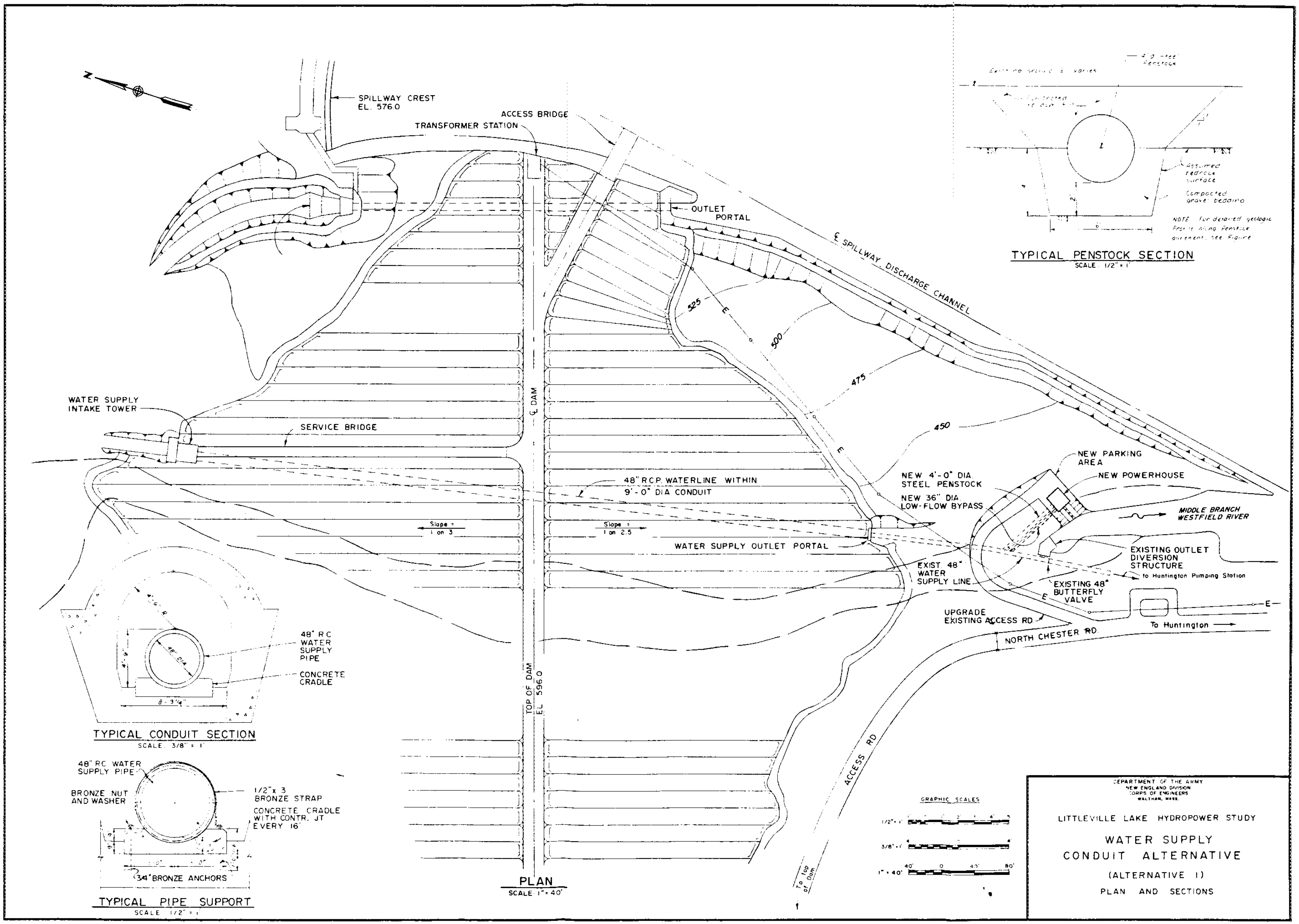
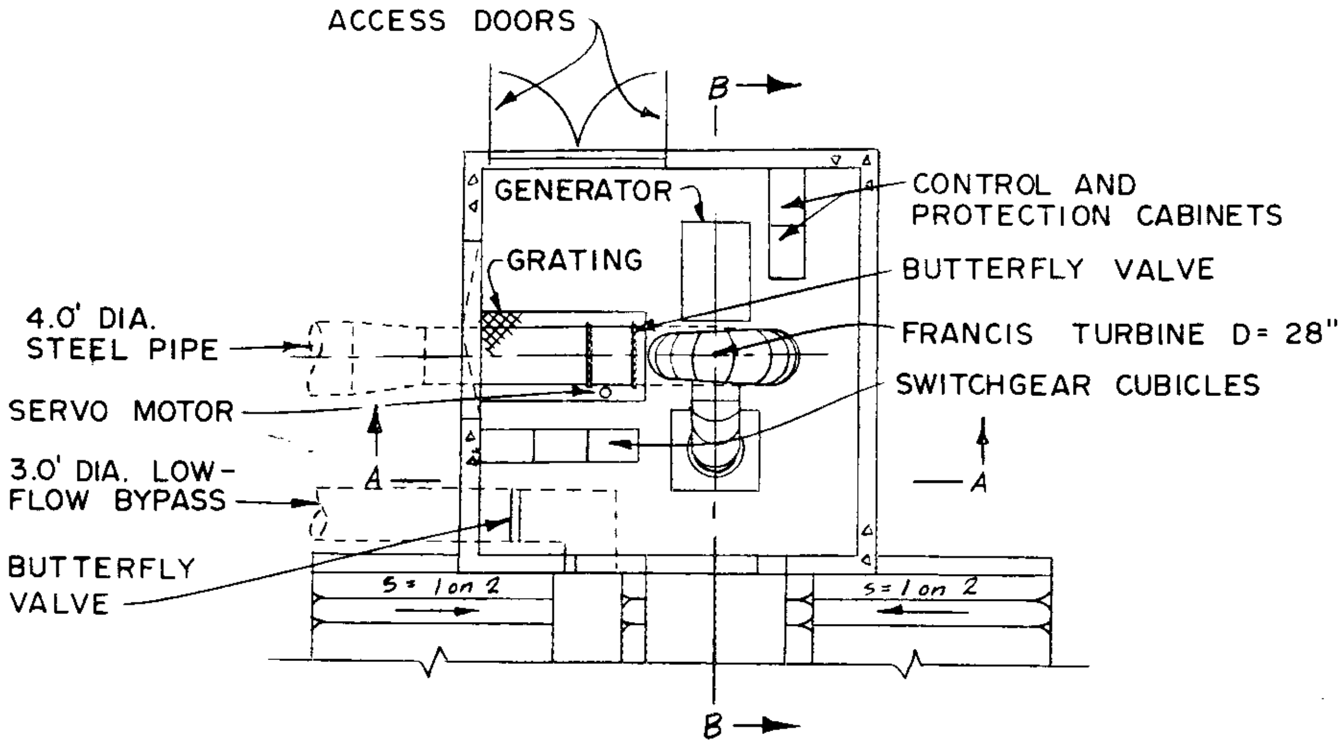

CORPS OF ENGINEERS
U. S. ARMY
RELOCATED GOSS HILL ROAD
INTAKE CHANNEL
WATER SUPPLY INTAKE TOWER
INTAKE CHANNEL
CONTROL WEIR
SERVICE BRIDGE
SPILLWAY — Crest El. 576.0
FLOOD CONTROL GATE SHAFT
TRANSFORMER STATION
ROTARY
DAM Top El. 596.0
MAINTENANCE ROAD
FLAG POLE
PARKING AREA
ACCESS BRIDGE
OUTLET PORTAL
PARKING AREA
OUTLET PORTAL
48" WATER SUPPLY LINE
TO: HUNTINGTON
OUTLET DIVERSION STRUCTURE
TURNAROUND
DISCHARGE CHANNEL
TOWN OF CHESTER
TOWN OF HUNTINGTON
HAMPDEN COUNTY
HAMPSHIRE COUNTY
NORTH CHESTER ROAD
MIDDLE BRANCH WESTFIELD RIVER
GRAPHIC SCALE
1" = 100'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
LITTLEVILLE LAKE
GENERAL PLAN
MIDDLE BRANCH WESTFIELD RIVER
HUNTINGTON, MASS.

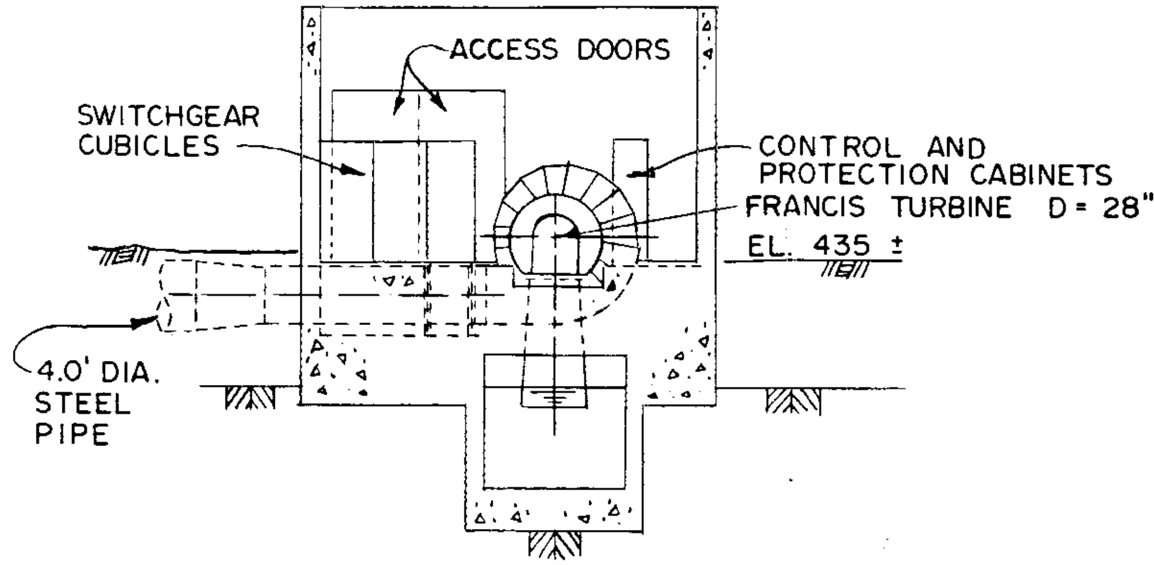
PLATE 2


CORPS OF ENGINEERS
U.S. ARMY
Excavate to slope 1 on 2.5 or to rock surface, whichever is higher
4'x 6' Sq. Concrete Bound w/ Brass Disk
Control Tower
Service Bridge
Diversion Conduit
Water Supply Conduit
Guard Rail
Slope 1 on 3
Slope 1 on 2.5
Curve Data
See Sheet No. 33A
MIDDLE BRANCH WESTFIELD RIVER
Existing North Chester Road
Limit of abandoned road
See Sheet No. 2
TURNAROUND
PLAN
NOTES
All elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate item numbers under which payment will be made.
For embankment Sections see Sheet No. 26
For Service Bridge Plan & Details see Sheet Nos. 91 to 99
Service bridge
Compacted gravel fill
Guard rail
Top of Dam El. 596.0
Rock slope protection
Gravel bedding
Compacted pervious fill
Compacted impervious fill
Compacted random fill
Compacted gravel bank fill
Compacted sand fill
Rock surface
Conduit Slope = 0.5%
48" Ø Water supply pipe
Rock berm
PROFILE ALONG ℄ CONDUIT
Record Drawing
Contract No. DA-19-016-CIVENG-62-329
SECTION A-A
SCALE 1" = 10'-0"
Existing Road
Slope 1 on 2
12" Road gravel
2½" Bituminous concrete
SECTION B-B
SCALE 1" = 10'-0"
GRAPHIC SCALE
6/7/63 Final Field Corrections
8-3-62 Plan note added (Am. 1)
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
WATER SUPPLY & SERVICE BRIDGE
PLAN AND PROFILE
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
DATE MARCH 1962
SCALE 1" = 40'
PLATE 3
CT-1-5766

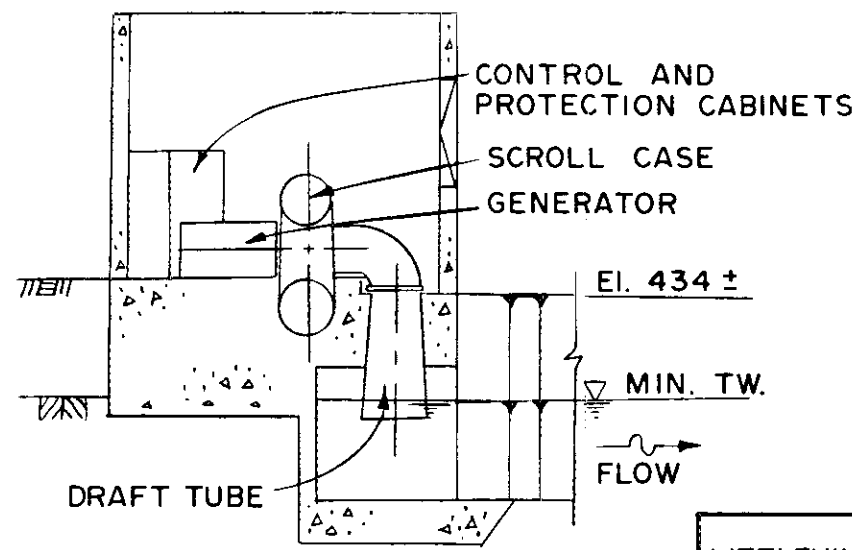

SPILLWAY CREST EL. 576.0
ACCESS BRIDGE
TRANSFORMER STATION
OUTLET PORTAL
℄ SPILLWAY DISCHARGE CHANNEL
525
500
475
450
E
℄ DAM
WATER SUPPLY INTAKE TOWER
SERVICE BRIDGE
48" R.C.P. WATERLINE WITHIN 9'-0" DIA CONDUIT
Slope = 1 on 3
Slope = 1 on 2.5
WATER SUPPLY OUTLET PORTAL
NEW 4'-0" DIA STEEL PENSTOCK
NEW 36" DIA LOW-FLOW BYPASS
NEW PARKING AREA
NEW POWERHOUSE
MIDDLE BRANCH WESTFIELD RIVER
EXISTING OUTLET DIVERSION STRUCTURE
to Huntington Pumping Station
EXIST 48" WATER SUPPLY LINE
EXISTING 48" BUTTERFLY VALVE
UPGRADE EXISTING ACCESS RD
NORTH CHESTER RD
To Huntington
ACCESS RD
To top of Dam
TOP OF DAM EL 596.0
PLAN
SCALE: 1" = 40'
TYPICAL PENSTOCK SECTION
SCALE: 1/2" = 1'
48" R C WATER SUPPLY PIPE
CONCRETE CRADLE
8'-3 1/4"
TYPICAL CONDUIT SECTION
SCALE: 3/8" = 1'
48" RC WATER SUPPLY PIPE
BRONZE NUT AND WASHER
1/2" x 3 BRONZE STRAP
CONCRETE CRADLE WITH CONTR. JT EVERY 16'
3/4" BRONZE ANCHORS
TYPICAL PIPE SUPPORT
SCALE: 1/2" = 1'
GRAPHIC SCALES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
LITTLEVILLE LAKE HYDROPOWER STUDY
WATER SUPPLY
CONDUIT ALTERNATIVE
(ALTERNATIVE 1)
PLAN AND SECTIONS



PLAN
N.T.S.



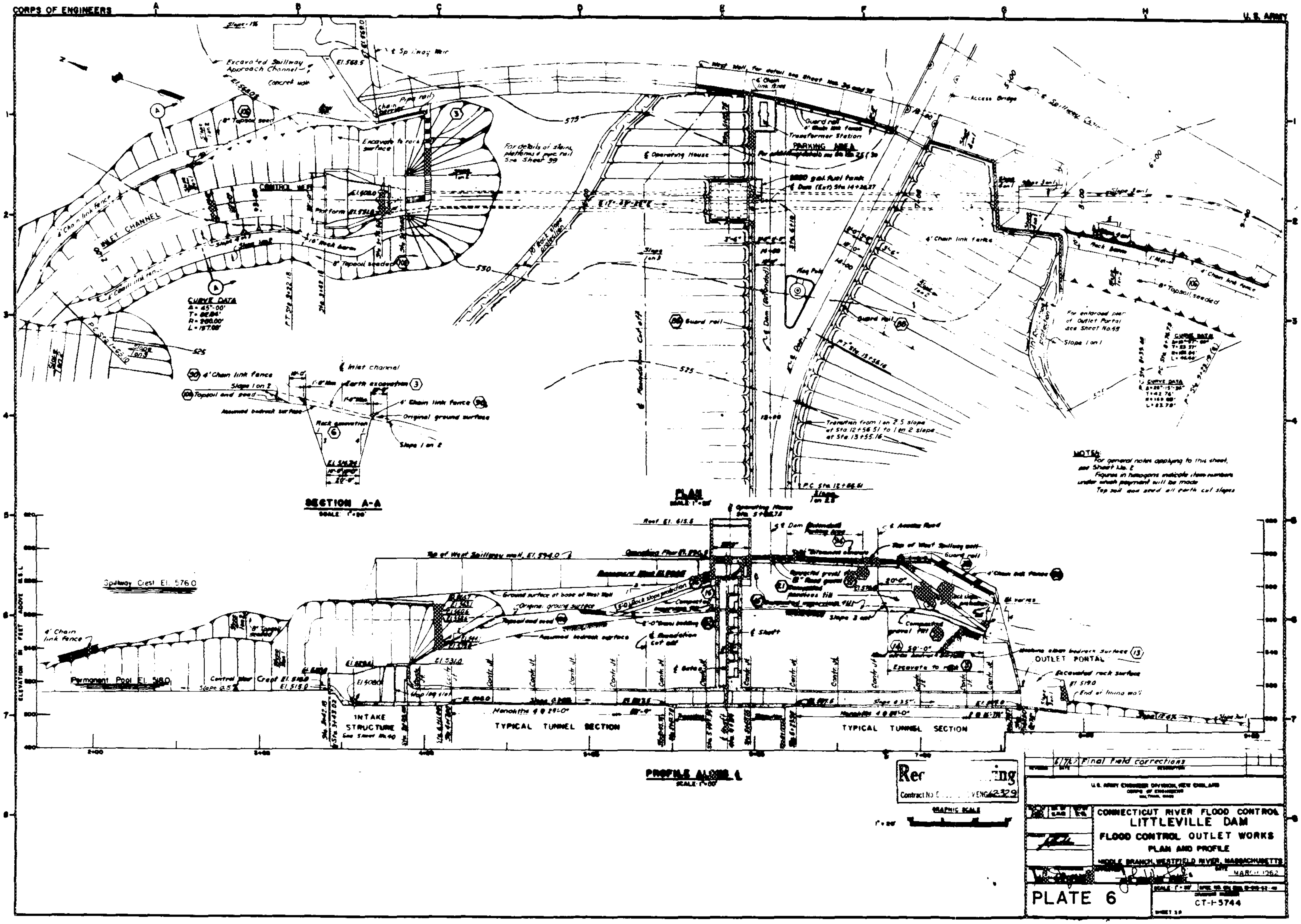
SECTION A-A
N.T.S.



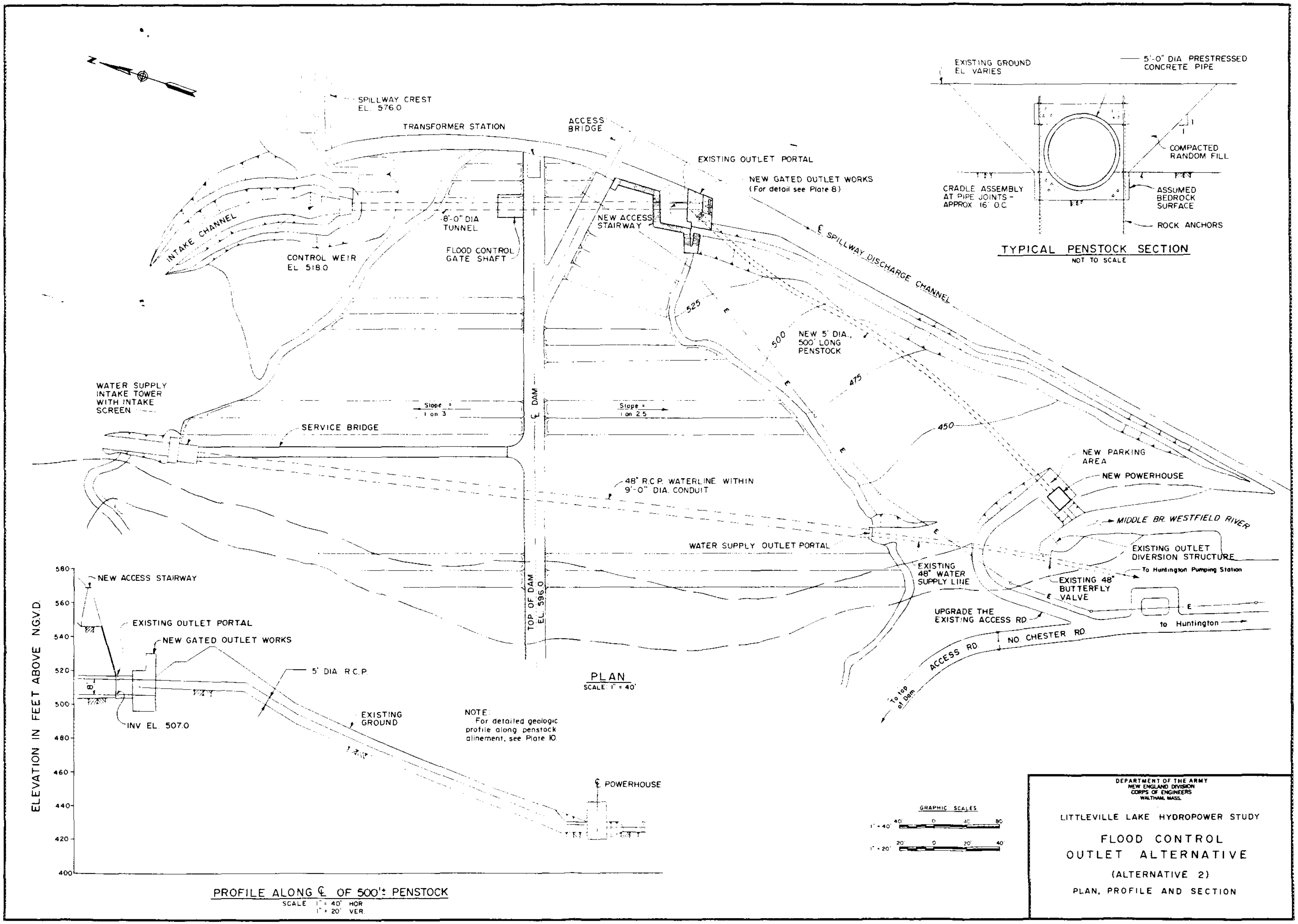
SECTION B-B
N.T.S.

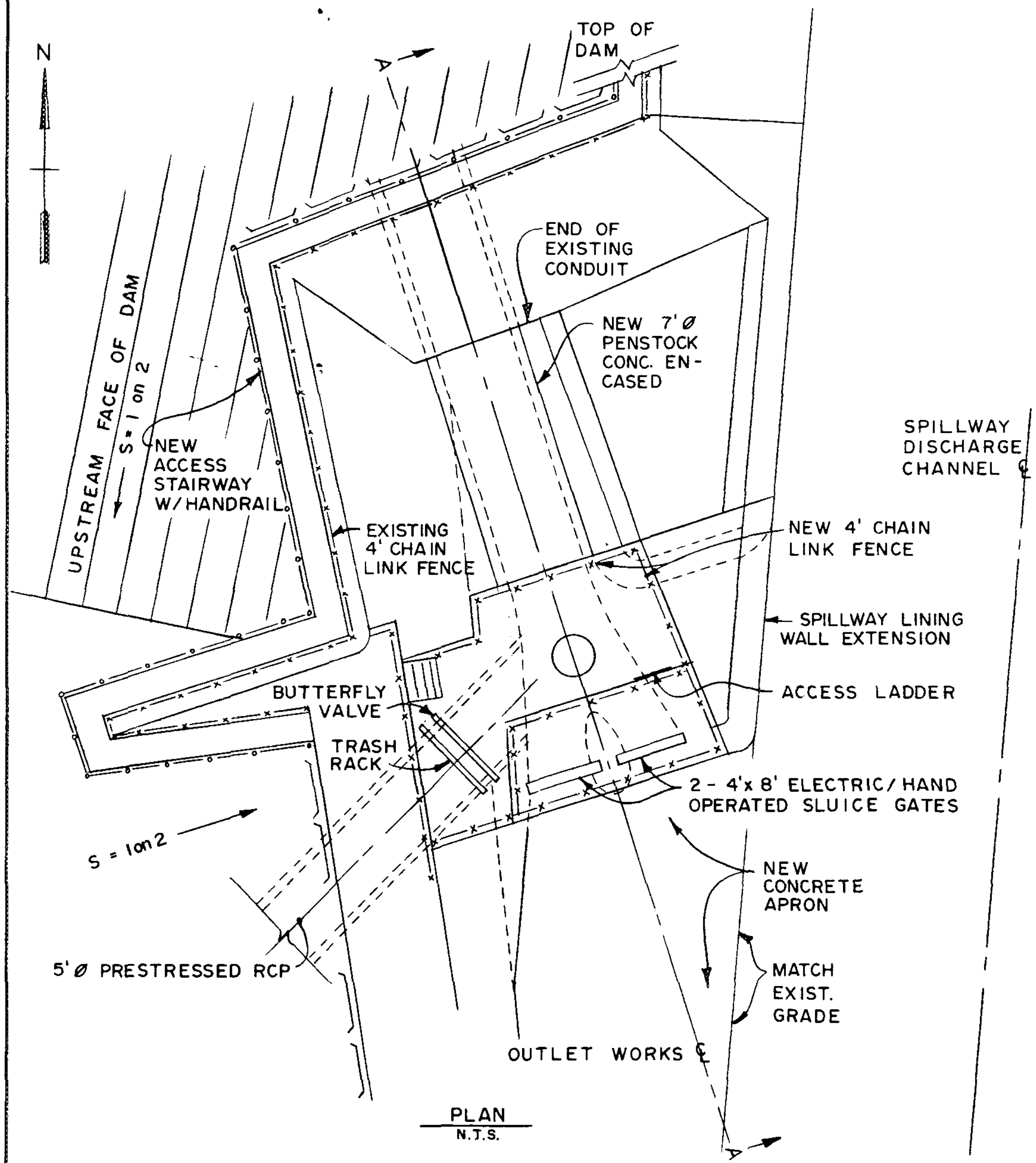
LITTLEVILLE LAKE HYDROPOWER STUDY

WATER SUPPLY
CONDUIT ALTERNATIVE
(ALTERNATIVE I)
POWERHOUSE
PLAN AND SECTIONS

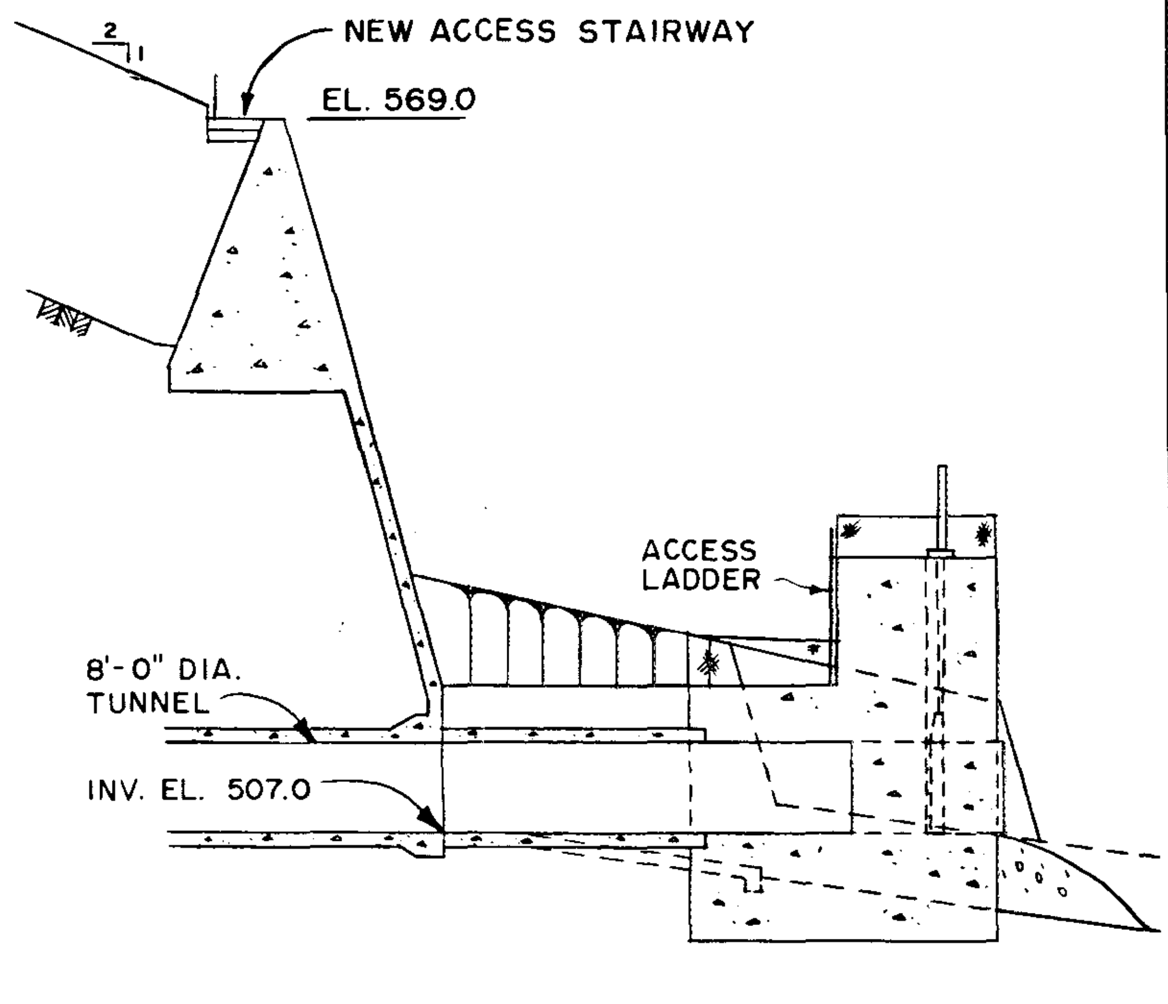


CORPS OF ENGINEERS
U.S. ARMY
INLET CHANNEL
CONTROL WEIR
CURVE DATA
Δ = 45°-00'
T = 82.84'
R = 200.00'
L = 157.08'
For details of stairs, platforms & pipe rail see Sheet 39
Operating House
PARKING AREA
Transformer Station
Access Bridge
Flag Pole
Guard rail
4' Chain link fence
8" Topsoil seeded
Rock berm
For enlarged plan of Outlet Portal see Sheet No. 55
Slope 1 on 1
Transition from 1 on 2.5 slope at Sta 12+56.51 to 1 on 2 slope at Sta 13+55.16
P.C. Sta 12+86.51
NOTES:
For general notes applying to this sheet, see Sheet No. 2
Figures in hexagons indicate item numbers under which payment will be made
Top soil and seed all earth cut slopes
PLAN
SECTION A-A
SCALE: 1" = 20'
Inlet channel
Earth excavation
4' Chain link fence
Original ground surface
Topsoil and seed
Assumed bedrock surface
Rock excavation
Slope 1 on 2
El. 514.24
Spillway Crest El. 576.0
Top of West Spillway wall El. 594.0
Permanent Pool El. 518.0
Ground surface at base of West Wall
Original ground surface
Assumed bedrock surface
Operating Floor
Roof El. 615.6
Shaft
Foundation cut off
Gates
INTAKE STRUCTURE
See Sheet No. 40
TYPICAL TUNNEL SECTION
OUTLET PORTAL
Excavated rock surface
End of lining wall
Excavate to rock
Compacted gravel fill
Impervious fill
ELEVATION IN FEET ABOVE M.S.L.
PROFILE ALONG ℄
SCALE: 1" = 20'
GRAPHIC SCALE
Final field corrections
Record Drawing
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
FLOOD CONTROL OUTLET WORKS
PLAN AND PROFILE
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
MARCH 1962
PLATE 6
CT-1-5744


SPILLWAY CREST EL. 576.0
TRANSFORMER STATION
ACCESS BRIDGE
EXISTING OUTLET PORTAL
NEW GATED OUTLET WORKS (For detail see Plate 8)
INTAKE CHANNEL
8'-0" DIA TUNNEL
NEW ACCESS STAIRWAY
CONTROL WEIR EL 518.0
FLOOD CONTROL GATE SHAFT
℄ SPILLWAY DISCHARGE CHANNEL
NEW 5' DIA., 500' LONG PENSTOCK
WATER SUPPLY INTAKE TOWER WITH INTAKE SCREEN
Slope = 1 on 3
℄ DAM
Slope = 1 on 2.5
SERVICE BRIDGE
48" R.C.P. WATERLINE WITHIN 9'-0" DIA. CONDUIT
NEW PARKING AREA
NEW POWERHOUSE
MIDDLE BR. WESTFIELD RIVER
WATER SUPPLY OUTLET PORTAL
EXISTING OUTLET DIVERSION STRUCTURE
To Huntington Pumping Station
EXISTING 48" WATER SUPPLY LINE
EXISTING 48" BUTTERFLY VALVE
TOP OF DAM EL. 596.0
UPGRADE THE EXISTING ACCESS RD.
to Huntington
NO. CHESTER RD.
ACCESS RD.
To top of Dam
PLAN
SCALE: 1" = 40'
EXISTING GROUND EL. VARIES
5'-0" DIA. PRESTRESSED CONCRETE PIPE
COMPACTED RANDOM FILL
CRADLE ASSEMBLY AT PIPE JOINTS - APPROX 16' O.C.
ASSUMED BEDROCK SURFACE
ROCK ANCHORS
TYPICAL PENSTOCK SECTION
NOT TO SCALE
ELEVATION IN FEET ABOVE N.G.V.D.
NEW ACCESS STAIRWAY
EXISTING OUTLET PORTAL
NEW GATED OUTLET WORKS
5' DIA. R.C.P.
INV. EL. 507.0
EXISTING GROUND
NOTE: For detailed geologic profile along penstock alinement, see Plate 10.
℄ POWERHOUSE
PROFILE ALONG ℄ OF 500'± PENSTOCK
SCALE 1" = 40' HOR 1" = 20' VER
GRAPHIC SCALES
1" = 40'
1" = 20'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
LITTLEVILLE LAKE HYDROPOWER STUDY
FLOOD CONTROL OUTLET ALTERNATIVE
(ALTERNATIVE 2)
PLAN, PROFILE AND SECTION



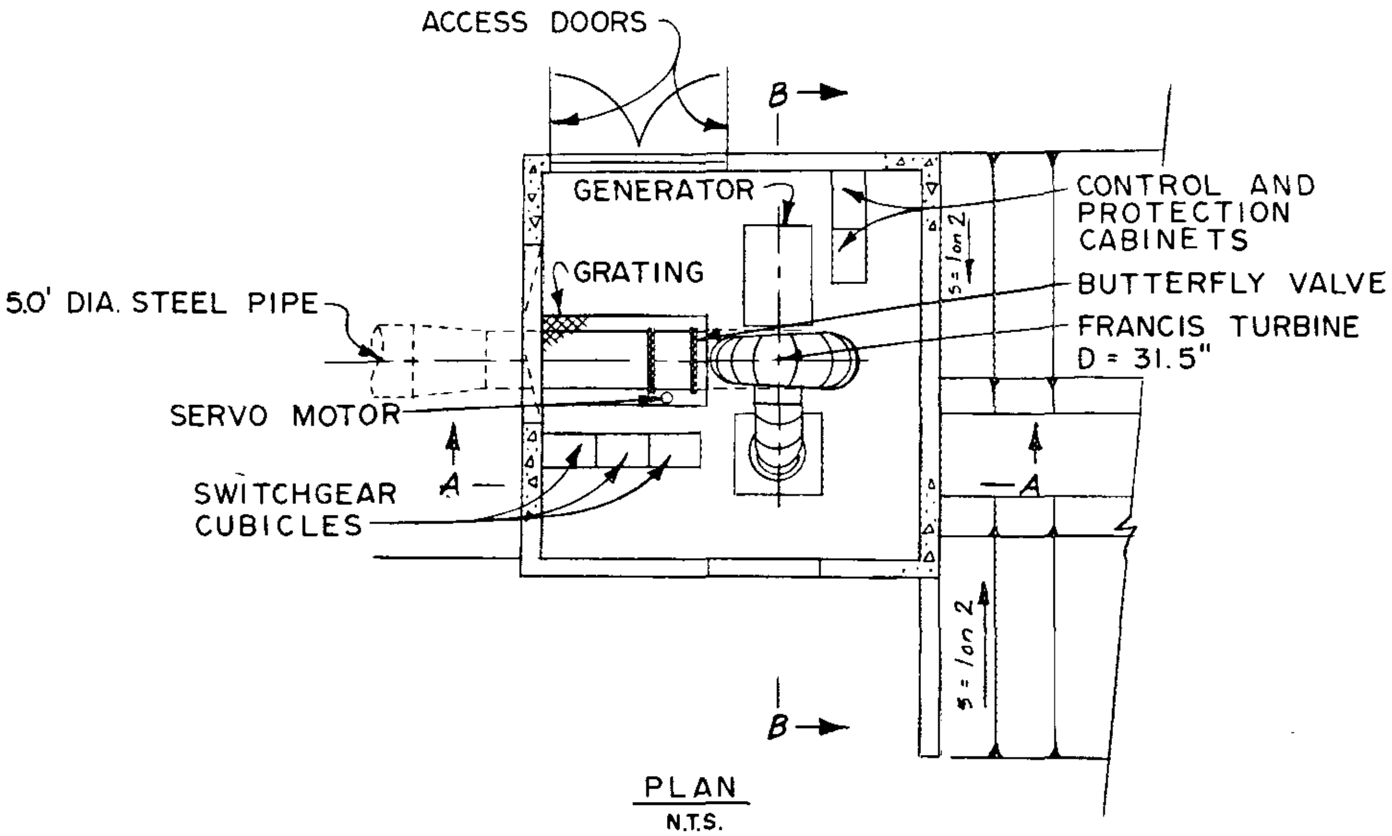
PLAN
N.T.S.



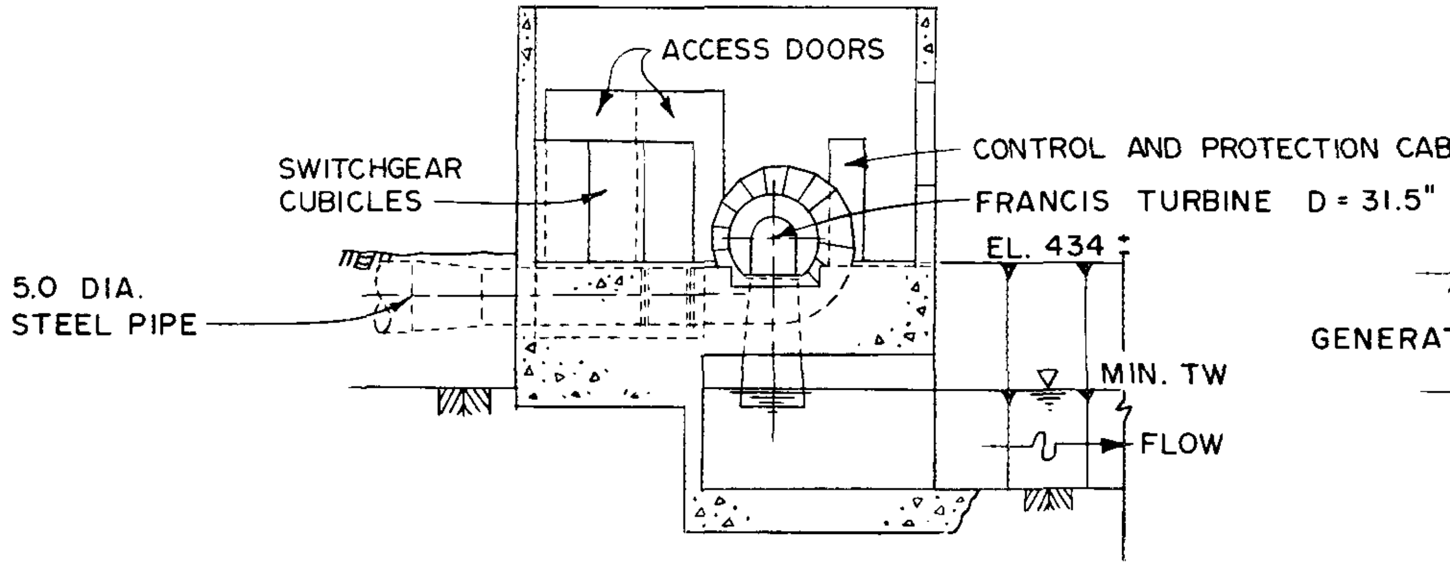
SECTION A-A
N.T.S.

LITTLEVILLE LAKE HYDROPOWER STUDY

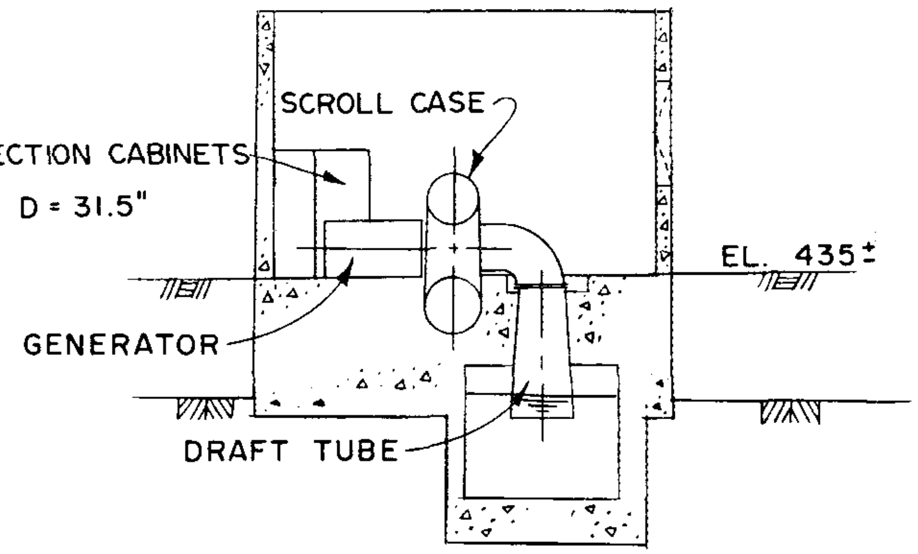
FLOOD CONTROL
OUTLET ALTERNATIVE
(ALTERNATIVE 2)
GATED OUTLET WORKS
PLAN AND SECTION



PLAN
N.T.S.



SECTION A-A
N.T.S.

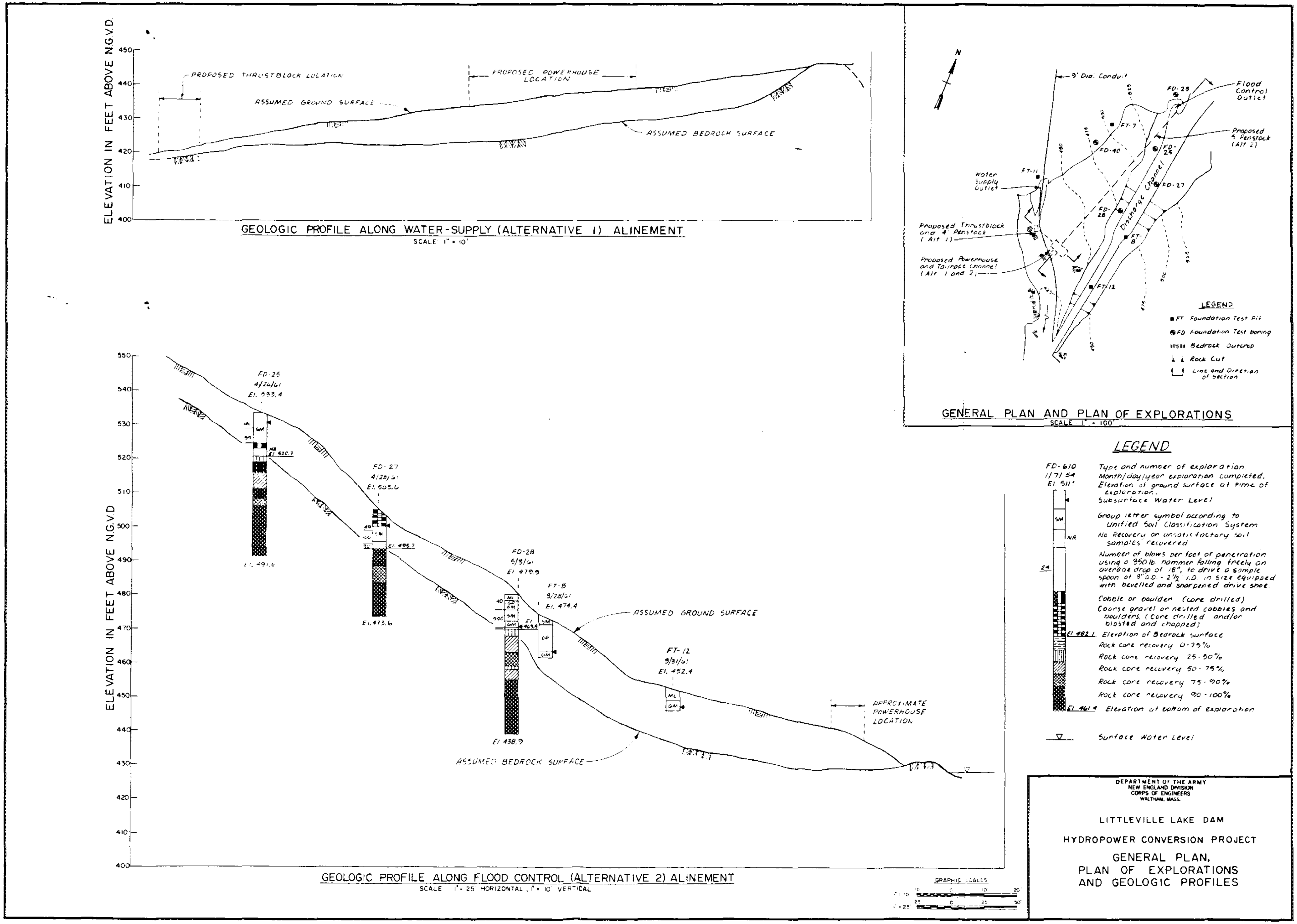


SECTION B-B
N.T.S.

LITTLEVILLE LAKE HYDROPOWER STUDY

FLOOD CONTROL
OUTLET ALTERNATIVE
(ALTERNATIVE 2)
POWERHOUSE
PLAN AND SECTIONS

PLATE 9



GEOLOGIC PROFILE ALONG WATER-SUPPLY (ALTERNATIVE 1) ALINEMENT
SCALE 1" = 10'
ELEVATION IN FEET ABOVE NGVD
PROPOSED THRUSTBLOCK LOCATION
PROPOSED POWERHOUSE LOCATION
ASSUMED GROUND SURFACE
ASSUMED BEDROCK SURFACE
GEOLOGIC PROFILE ALONG FLOOD CONTROL (ALTERNATIVE 2) ALINEMENT
SCALE 1" = 25' HORIZONTAL, 1" = 10' VERTICAL
FD-25 4/26/61 El. 533.4
El. 520.7
El. 491.6
FD-27 4/28/61 El. 505.6
El. 498.7
El. 473.6
FD-28 5/3/61 El. 479.9
El. 469.9
El. 438.9
FT-B 3/28/61 El. 474.4
FT-12 3/31/61 El. 452.4
APPROXIMATE POWERHOUSE LOCATION
GENERAL PLAN AND PLAN OF EXPLORATIONS
SCALE 1" = 100'
N
9' Dia. Conduit
Flood Control Outlet
Proposed 5' Penstock (Alt 2)
Water Supply Outlet
Proposed Thrustblock and 4' Penstock (Alt 1)
Proposed Powerhouse and Tailrace Channel (Alt 1 and 2)
Discharge Channel
FD-25
FT-7
FD-40
FD-25
FD-27
FT-11
FD-28
FT-8
FT-12
LEGEND
FT Foundation Test Pit
FD Foundation Test Boring
Bedrock Outcrop
Rock Cut
Line and Direction of Section
LEGEND
FD-610 Type and number of exploration.
1/7/54 Month/day/year exploration completed.
El. 511± Elevation of ground surface at time of exploration.
Subsurface Water Level
SM Group letter symbol according to Unified Soil Classification System
NR No Recovery or unsatisfactory soil samples recovered
24 Number of blows per foot of penetration using a 350 lb. hammer falling freely on average drop of 18", to drive a sample spoon of 3" O.D. - 2 1/2" I.D. in size equipped with bevelled and sharpened drive shoe.
Cobble or boulder (core drilled)
Course gravel or nested cobbles and boulders (core drilled and/or blasted and chopped)
El. 482.1 Elevation of Bedrock surface
Rock core recovery 0-25%
Rock core recovery 25-50%
Rock core recovery 50-75%
Rock core recovery 75-90%
Rock core recovery 90-100%
El. 461.4 Elevation at bottom of exploration
Surface Water Level
GRAPHIC SCALES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
LITTLEVILLE LAKE DAM
HYDROPOWER CONVERSION PROJECT
GENERAL PLAN,
PLAN OF EXPLORATIONS
AND GEOLOGIC PROFILES

LITTLEVILLE LAKE HYDROPOWER
APPENDIX A
HYDROLOGIC ANALYSIS

LITTLEVILLE LAKE HYDROPOWER
APPENDIX A
HYDROLOGIC ANALYSIS

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PURPOSE

This appendix presents the hydrologic engineering information and analysis pertinent to stage III planning studies for hydropower development at Littleville Dam. Included are sections describing the basin and its hydrology, the hydrologic analysis of alternative plans of development, project operation, and the possible impact of future water supply use on hydropower potential.

BACKGROUND

A preliminary feasibility study (stage II) completed in October 1980, investigated four alternative plans for hydropower development at Littleville Dam, two of which warranted further more detailed study. One alternative utilized the existing 48-inch water supply line as a penstock while the other alternative required the construction of a new penstock, utilizing the existing flood control outlet works independent of the water supply line. Current studies considered the proposed hydropower operation at Littleville Dam strictly as "run of river", utilizing the flow of the stream as it occurs, with no appreciable storage regulation. It was also assumed that any hydropower development at Littleville Lake would allow no encroachment into the projects authorized flood control storage as well as no modifications to the current flood control operations at the project.

HYDROLOGIC CHARACTERISTICS

General

Littleville Lake is a Corps of Engineers project located in the Westfield River Basin, a tributary to the Connecticut River, in west-central Massachusetts at approximately 42°16' north latitude and 72°53' west longitude. It is a multipurpose water supply and flood control project completed in 1965. The Westfield River has a drainage area of 517 square miles. Littleville Dam, located on the Middle Branch Westfield River, has a drainage area of 52.3 square miles. A map of the Westfield River watershed is shown on plate A-1. A general plan of Littleville Dam is shown on plate A-2.

Littleville Dam has two separate reservoir outlet works - one for flood control releases and the other for water supply releases. The flood control outlet works consist of an intake channel, gates, tower and outlet tunnel. Just upstream of the intake structure is a 30-foot long concrete weir with crest elevation 518 feet NGVD. This weir serves to maintain the pool at approximately elevation 518 feet NGVD, thereby minimizing required pool level monitoring and gate operation. A plan and profile of the flood control outlet works are shown on plate A-3. The main components of the water supply outlet works consist of an intake channel, wet well tower with four 36-inch diameter gates at different elevations for drawing water from various levels, an outlet conduit and an outlet channel. The outlet conduit consists of a 48-inch diameter concrete pipeline, installed within a 9-foot arch-shaped conduit, and extends from the intake tower to a low flow diversion structure, approximately 215 feet downstream of Littleville Dam, for a total length of about 1,000 feet, then on to a downstream pumping station in Huntington. A plan and profile of the water supply outlet works are shown on plate A-4.

Watershed

The Westfield River watershed, the fifth largest tributary area to the Connecticut River, covers a large portion of the eastern slopes of the Berkshires in western Massachusetts. The basin is located within the confines of Berkshire, Franklin, Hampden and Hampshire Counties, with a small portion extending into Hartford County, Connecticut. The watershed has a total drainage area of 517 square miles. Elevations in the watershed vary from 2,505 feet NGVD at Borden Mountain in the headwaters to about 40 feet NGVD at the confluence with the Connecticut River in Agawam and West Springfield, Massachusetts. Topography of the upper portion of the Westfield River basin, above the city of Westfield, is rough and rocky and is drained by many small streams which are conducive to rapid runoff. About 2 miles downstream of Westfield the watershed is bisected by a row of hills, Provin and East Mountains, which are a section of the Holyoke range.

The Westfield River has three principal headwater tributaries: the main stem Westfield, Middle Branch and West Branch. Littleville Dam is located on the Middle Branch of the Westfield River, about 1 mile upstream of its confluence with the main river. The Middle Branch originates near the Peru-Worthington town line in northwest Worthington and flows in a southeasterly direction for about 16 miles to its confluence with the Westfield River at Goss Heights in Huntington. It has a drainage area of about 53 square miles. Another Corps of Engineers project, Knightville Dam, is located on the main stem Westfield River, 4 miles north of Huntington and about 27.5 miles above the confluence of the Westfield River with the Connecticut River in West Springfield. The Westfield River at Knightville Dam has a total drainage area of 162 square miles. The three principal tributaries as well as the locations of Littleville and Knightville Dams are shown on the watershed map on plate A-1.

Climate

The Westfield watershed has a cool semihumid climate typical of the New England region. The average annual temperature is about 45 degrees Fahrenheit with monthly averages varying from about 69 degrees in July to about 21 degrees in January. Extremes in temperature range from summertime highs in the nineties to wintertime lows in the minus twenties. The average annual precipitation over the watershed is approximately 46 inches, uniformly distributed throughout the year, generally occurring as periodic storm fronts of 1 to 2 days duration. Mean, maximum and minimum monthly precipitation, as recorded at Knightville Dam, are listed in table A-1. Much of the winter precipitation occurs as snow with an average annual snowfall of about 56 inches. The snowpack usually reaches a maximum in early March with an average maximum water equivalent of about 4.0 inches.

Streamflow

The average annual streamflow in the Westfield basin is about 55 percent of the mean annual precipitation, or 25.7 inches of runoff, equivalent to an average runoff rate of about 2 cubic feet per second (cfs) per square mile of watershed area. Based on 61 years of streamflow records on the Westfield River at Westfield, Massachusetts, the maximum annual runoff was 44.1 inches in 1928 and the minimum annual runoff was 11.1 inches in 1965. Though precipitation is quite uniformly distributed throughout the year, the melting of the winter snow cover results in about 50 percent of the annual runoff during the months of March, April and May. Flows are usually lowest during the months of July, August and September.

The USGS gaging station 01180500 at Goss Heights, Massachusetts is located on the Middle Branch just downstream of Littleville Dam. The gage has recorded flows from its 52.6 square mile drainage area since 1911. As water supply diversions from Littleville Dam have not yet commenced and because the principal operation is for short term flood control, the monthly flows, recorded at the downstream gaging station, at Goss Heights, are considered representative of the natural monthly streamflows at Littleville. A summary of average, maximum and minimum monthly flows, recorded at Goss Heights, are listed in table A-2. An average annual flow duration curve (discharge rate versus percent of time) based on an analysis of daily flow records for the period of record is shown on plate A-5. Individual monthly flow duration curves, used to calculate monthly potential energy generation, are shown on plates A-6 through A-9.

TABLE A-1

MONTHLY PRECIPITATION IN INCHES
KNIGHTVILLE DAM, MASSACHUSETTS
(Period of Record 1948-1980)

Month	Mean	Maximum	Minimum
January	3.49	11.84	0.75
February	3.00	5.11	0.75
March	4.01	10.18	1.28
April	3.74	5.97	0.82
May	3.67	6.73	0.95
June	3.52	9.12	0.57
July	3.46	8.14	1.12
August	3.78	15.27	1.06
September	3.55	8.06	1.08
October	3.62	16.95	0.42
November	4.17	8.11	0.81
December	4.06	9.38	0.65
Annual	44.07	62.36	32.15

TABLE A-2

AVERAGE MONTHLY FLOWS (1911-1979)
MIDDLE BRANCH AT GOSS HEIGHTS, MASSACHUSETTS
(Drainage Area = 52.6 Square Miles)

Month	Average Flow		Percent of Annual Runoff	Maximum Monthly		Minimum Monthly	
	CFS	Inches		CFS	Inches	CFS	Inches
January	100.6	2.2	8.0	255	5.6	15	0.3
February	89.4	1.8	6.6	247	4.9	17	0.3
March	218.5	4.8	17.5	653	14.3	46	1.0
April	292.9	6.2	22.6	594	12.6	54	1.1
May	138.1	3.0	10.9	280	6.1	35	0.8
June	68.5	1.5	5.5	351	7.4	4	0.1
July	34.2	0.7	2.6	150	3.3	5	0.1
August	32.1	0.7	2.6	316	6.9	3	0.1
September	39.8	0.8	2.9	328	7.0	1	---
October	53.8	1.2	4.4	507	11.1	4	0.1
November	97.7	2.1	7.7	366	7.8	9	0.2
December	107.5	2.4	8.8	351	7.7	18	0.4
Annual	106.1	27.4		182	47.3	43	11.2

Reservoir Storage

Littleville Reservoir has a total storage capacity of 32,400 acre-feet between invert elevation 432 and spillway crest elevation 576 feet NGVD. Of the total storage, 9,400 acre-feet, between elevations 432 and 518 feet NGVD, is owned by the city of Springfield, Massachusetts and is used as a backup to their domestic water supply system. This 9,400 acre-feet is equivalent to about 3.4 inches of runoff from the contributing 52.3 square mile watershed area above Littleville Dam. The remaining 23,000 acre-feet is for flood control storage and is equivalent to 8.3 inches of runoff from the contributing watershed area. The normal pool elevation at Littleville Dam is elevation 518 feet NGVD, except during periods of short duration flood regulation.

Pertinent data on storages and elevations at Littleville Dam is listed in table A-3. A storage-capacity curve is shown on plate A-10.

Water Supply

As mentioned previously, the 9,400 acre-feet of storage at Littleville Dam (between elevations 432 and 518 feet NGVD), is owned by the city of Springfield as a backup to their water supply system. Water supply diversions from Littleville are made through a 48-inch diameter water supply pipeline which conveys flow through the Huntington pump station into the Cobble Mountain reservoir on the Little River. Cobble Mountain reservoir has a drainage area of 48.5 square miles with a total capacity of about 70,000 acre-feet and is the principal water supply source for the city of Springfield. Present demand on the Springfield water supply system is about 37 MGD with little change over the past few years, as shown in table A-4. The existing Springfield system has a dependable yield of about 44 MGD exclusive of Littleville, and with diversions from Littleville the dependable yield could be as high as 70 MGD. Since the completion of Littleville Dam in 1965, water supply diversions to Cobble Mountain have not been required, however the potential for diversions exists and their effect on the hydropower potential at Littleville Dam is discussed in the last section of this appendix.

Minimum Releases

Minimum releases from Littleville are generally that of the natural streamflow less evaporation losses. A minimum release of about 10 to 20 cfs is usually maintained at Littleville Dam during periods of flood control regulation in order to sustain downstream fish life. In addition,

TABLE A-3

STORAGE-ELEVATION DATA
LITTLEVILLE DAM
(Drainage Area = 52.3 Square Miles)

	Elevation (ft. NGVD)	Stage (ft)	Pool Area (acres)	Storage (ac-ft)	Runoff (inches)
Bottom of Water Supply Pool	432	0	0	0	0
Top of Water Supply	518	86	275	9,400	3.4
Spillway Crest	576	144	510	23,000 (net)	8.3 (net)
Maximum Surcharge	591	159	584	31,200 (net)	11.2 (net)
Top of Dam	596	164	-	-	-

TABLE A-4

CITY OF SPRINGFIELD, MASSACHUSETTS
WATER SUPPLY SYSTEM
AVERAGE DAILY USE IN MILLION GALLONS

Year	Use	Year	Use	Year	Use	Year	Use
1912	10.6	1931	15.2	1950	26.6	1969	39.2
1913	10.7	1932	14.1	1951	28.4	1970	40.0
1914	10.8	1933	14.1	1952	27.5	1971	39.3
1915	10.2	1934	14.8	1953	28.9	1972	35.3
1916	11.4	1935	14.8	1954	28.1	1973	37.9
1917	12.1	1936	16.0	1955	31.4	1974	37.7
1918	13.3	1937	15.8	1956	33.0	1975	36.3
1919	12.1	1938	15.4	1957	35.7	1976	37.5
1920	12.9	1939	16.4	1958	32.9	1977	34.5
1921	12.8	1940	16.5	1959	37.0	1978	35.7
1922	12.5	1941	18.7	1960	35.5	1979	36.3
1923	13.9	1942	18.8	1961	35.8	1980	35.2
1924	14.2	1943	20.9	1962	37.2		
1925	14.5	1944	21.8	1963	36.4		
1926	14.4	1945	22.2	1964	38.4		
1927	14.5	1946	22.9	1965	36.9		
1928	14.9	1947	24.9	1966	29.4		
1929	16.2	1948	25.6	1967	32.5		
1930	16.1	1949	25.8	1968	38.3		

section 10 in chapter 628 of the Acts and Resolves of the Commonwealth of Massachusetts, authorizes the Massachusetts Water Resources Commission to fix and regulate low flow requirements from Littleville Lake after water supply diversions have been initiated. The Commission established a minimum flow of 5 cfs in 1969.

HYDROLOGIC ANALYSIS

Hydropower Potential

General

The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. This gravitational potential energy is tranformed into mechanical energy by turning a turbine which in turn creates electrical energy by turning a generator. The potential rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{QHE}{11.8}$$

where:

P = Power capacity in kilowatts

Q = Rate of discharge in cubic feet per second

H = Net hydraulic head in feet

E = Combined turbine and generator efficiencies

The potential amount of power generation over a period of time, "energy", is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream, river or lake is a function of: a) the average annual streamflow, and b) the average annual hvdraulic head. Both the rate of discharge and the head are quantities which may fluctuate, therefore, it is the magnitude of these two quantities and their variability that determine the potential energy of a site and its dependability.

Because of the seasonally low flow character of the Middle Branch Westfield River and the lack of hydropower storage for monthly or seasonal storage regulation, any hydropower development at Littleville would be viewed generally as "run-of river". Though capacity would not be dependable, it is noted that with a permanent hydropower pool at elevation 518, the capability of providing "spinning reserve" capacity for emergency short term generation would exist.

At Littleville Dam there exists a normal pool level at elevation 518 feet NGVD and tailwater elevation at about 425, thus providing a gross hydraulic head of 93 feet. Net power head was computed by subtracting hydraulic losses from the gross head under varying operating discharges for each alternative. The overall plant efficiency is the turbine efficiency times the generator efficiency. Turbine efficiency was assumed to vary throughout the anticipated hydraulic operating range, in accordance with the turbine performance curves, shown on plate A-11. Turbine efficiency was considered equal to 88 percent at rated capacity and generator efficiency was considered to be constant at 95 percent throughout its operating load range.

Alternative 1

<u>Description</u>. With this alternative, a powerhouse would be located approximately 200 feet downstream from the toe of the dam. Flows would be diverted to the powerhouse by tapping off the existing 48-inch diameter water supply conduit. The existing 48-inch diameter reinforced concrete water supply conduit that would serve as the penstock is about 1,000 feet long. The tailrace would discharge to the Middle Branch of the Westfield River downstream of the dam.

<u>Head Loss versus Installed Capacity</u>. In determining the power potential of a hydropower project at Littleville Dam the net generating head was computed. For alternative 1, the net head was computed by subtracting the intake, exit and penstock losses from the gross head of 93 feet. A simplified representation of the Bernoulli equation, expressing total head loss (H_T) as the product of the total loss coefficient (K_T) times the velocity head ($\frac{V2}{2g}$) was used.

$$H_T = K_T \frac{V^2}{2g}$$

In computing the loss coefficients for intake and exit, it was assumed that some velocity head recovery through the expanding draft tube of the turbine would occur and therefore a combined intake and exit loss coefficient of

0.5 was used. In computing penstock losses, friction was considered the primary loss and was computed by the Manning's equation, as applied to closed conduit flow.

$$K_f = \frac{(29.1)n^2L}{R^{4/3}}$$

where for alternative 1:

- n = 0.015 for the existing 48-inch diameter reinforced concrete water supply conduit
- L = 1,000 feet long
- R = 1.0 for the 48-inch diameter conduit

The coefficient of friction (K_f) was computed to be 6.5. The total combined head loss (feet) was therefore equal to $7.0\ \frac{V^2}{2g}$. Manning's equation was considered applicable for the relatively low velocity flow condition and was adopted in lieu of the Darcy-Weisbach formula because of ease of application. Results using the two methods were found to be within 5 percent of each other. Plate A-12 shows the corresponding net head versus installed capacity (cfs) for alternative 1.

Annual Energy versus Installed Capacity. Alternative 1 plant capacities were analyzed by developing capacity energy relationships for the Littleville plant using annual flow duration curves of the Middle Branch Westfield River, developed from daily flow data. Since a flow duration curve is a measure of the magnitude and variability of flow, the area under the flow duration curve, within operating limits of the selected facility, establishes the potential average annual energy to be realized at the site. The operating limitations were in accordance with the turbine performance characteristics shown on plate A-11. Operating flow range of single units was assumed from 40 to 105 percent of design capacity. Net head varied with discharge in accordance with plate A-12. An example of average annual energy computation for a single unit installation is shown on plate A-13. Relationships between capacity and average annual energies for a single unit installation are graphically shown on plate A-14.

Multiple Units. The potential energy of a project is proportional to the area under the flow duration curve. For the same total plant capacity, a multiple unit facility, can produce more energy since it can generate at lower flows and higher efficiencies. For alternative 1, multiple units were investigated assuming two units of equal size. Average annual energies were computed for a range of installed capacities and are comparatively shown on plate A-14.

Table A-5 presents a summary of the hydropotential at Littleville Dam for alternative 1.

Alternative 2

Description. With this alternative, a separate penstock, independent of the existing water supply facilities would extend from the higher level flood control outlet works to about 500 feet down the downstream face of the dam where a powerhouse would be located at the downstream toe of the dam. The tailrace would discharge to the Middle Branch of the Westfield River downstream of the dam.

Head Loss and Penstock Sizing. The net generating head was computed, as in alternative 1, by use of the Bernoulli equation and the Manning equation. In alternative 1, computations were based on one existing penstock size, however in alternative 2, since no penstock exists, losses varied with proposed penstock size. Penstock sizes versus velocities for a range of installed capacities are listed in table A-6. A 5-foot diameter was considered appropriate based on both velocity and head loss comparisons. In computing hydraulic losses, the coefficiencts of intake, exit, bend and friction were computed. Owing to the alignment of the proposed penstock the total combined intake, exit and bend loss coefficients of 1.5 was used. In computing the friction coefficient, Manning's equation was used:

$$K_f = \frac{(29.1)n^2L}{R^{4/3}}$$

where for alternative 2:

n = 0.015 assuming reinforced concrete

L = 500 feet in length

R = hydraulic radius of 1.25 for a 5-foot diameter penstock

The coefficient of friction (K_f) was computed to be about 3.0, yielding

TABLE A-5

SUMMARY OF HYDROPOTENTIAL AT LITTLEVILLE DAM

Hydraulic Capacity (cfs)	Net Head (ft)	Installed Capacity (kw)	Single Unit Configuration: No. Units	Single Unit Configuration: Avg Ann Energy (mwh)	Single Unit Configuration: Avg Ann Plant Factor	Multiple Units of Equal Capacity Configuration: No. Units	Multiple Units of Equal Capacity Configuration: Avg Ann Energy (mwh)	Multiple Units of Equal Capacity Configuration: Avg Ann Plant Factor
ALTERNATIVE NO. 1								
40	91	258	1	1,675	0.74	2	1,773	0.78
60	91	387	1	2,054	0.61	2	2,335	0.69
100	86	625	1	2,649	0.48	2	2,960	0.54
140	79	800	1	2,674	0.38	2	3,194	0.46
190	69	919	1	2,612	0.32	2	3,141	0.39
ALTERNATIVE NO. 2								
40	91	258	1	1,675	0.74	2	1,773	0.78
60	91	387	1	2,054	0.61	2	2,335	0.69
120	89	750	1	2,720	0.41	2	3,200	0.49
150	86	910	1	2,860	0.36	2	3,432	0.43
200	84	1,190	1	2,980	0.29	2	3,680	0.35

a total combined head loss equal to $4.5 \frac{V^2}{2g}$. Plate A-12 shows the corresponding net head versus installed capacity for alternative 2.

TABLE A-6

PENSTOCK FLOW VELOCITIES

Plant Loading (cfs)	Velocities (ft/sec) 7 ft. Diameter	6 ft. Diameter	5 ft. Diameter
120	3.1	4.2	6.1
150	4	5.4	7.8
170	4.5	6.0	8.7
190	5	6.8	9.8
230	6	8.1	11.7
300	8	10.8	15.7

Annual Energy versus Installed Capacity. For alternative 2, average annual energy was computed for a range of installed capacities considering a single unit installation. Turbine performance characteristics, are shown on plate A-11. The operating flow range of individual units was from 40 to 105 percent of design capacity. Net head varied with discharge in accordance with plate A-12. An example of average annual energy computation for a single unit installation is shown on plate A-13 . Relationships between capacity and average annual energies for a single unit installation are graphically shown on plate A-15.

Multiple Units. As in alternative 1, multiple units for alternative 2 were investigated assuming two units of equal size. Average annual energies were computed for a range of installed capacities and are comparatively shown on plate A-15

Table A-5 presents a summary of the hydropotential at Littleville Dam for alternative 2.

Recommended Plan

All economic scoping analyses of both alternatives, were performed by the Economic and Social Analysis Section, Planning Division of the New England Division as presented in other parts of the main report. The economic analyses presented therein were based on results of hydrologic as well as engineering analyses and serve as the basis for the selection of the recommended hydropower installation at the Littleville Lake project.

Monthly Generation Pattern

Monthly flow duration curves, based on average daily flows recorded at the USGS gaging station at Goss Heights, were prepared in order to determine the monthly average energy potential, as well as aid in determining the eventual marketability of the generated energy. The individual monthly flow duration curves are presented on plates A-6 through A-9. Also included on plates A-6 through A-9 are the respective potential average monthly energy versus installed capacity relationships for single unit configurations for each alternative.

For a range of installed capacities the monthly average energy values were compared with the corresponding annual energy values resulting in an approximate monthly average generation pattern (percentage of average annual capability), shown on plate A-16.

The spring months of March through May are maximum energy months due to high runoff that time of year and combine to yield about 50 percent of the average annual potential energy capability, whereas the lowest energy months of July through September yield only about 6 percent of the annual capability.

Project Operation

General

Littleville Dam has two separate reservoir outlet works - one for water supply releases considered under alternative 1 and another for flood control releases considered under alternative 2. A key assumption in this study was that project outflows and operations would not be changed in order to accommodate power production. It was therefore considered that any development of hydropower at Littleville Dam would be strictly run-of-river with no provisions for pondage either on a short term or long term basis. Such a development would be considered to have no dependable capacity and would therefore be viewed mainly as a "fuel saver".

Alternative 1

Littleville Lake is presently maintained at elevation 518 feet NGVD with outflow equal to inflow except during periodic flood regulation. All discharges are presently made through the flood control outlet works. Alternative 1 would divert flows through the turbine for power by tapping off the existing 48-inch water supply conduit at the downstream toe of the dam. Under this alternative, discharges would pass through the water supply conduit while still maintaining flood control release capabilities through the flood control outlet works. Any flows in excess of turbine capacity, would be released through the flood control outlet works. In accordance with the monthly flow duration and energy potential curves on plates A-6 through A-9, it is expected that a project at Littleville Lake would operate at near design capacity through March, April and May, due to the availability of high flows and would probably operate intermittently during the historic low flow periods of July through October. With alternative 1, some waters could be diverted for water supply, coincident, but with some loss in net power head and energy. The last section of this appendix addresses in more detail the effect of water supply releases on the average annual energy potential of a hydroproject at Littleville Dam.

Alternative 2

With this alternative, a separate penstock, independent of the existing water supply facilities would extend from the higher level flood control outlet works about 500 feet along the downstream face of the dam to a powerhouse located at the toe of the dam. The tailrace would discharge to the Middle Branch of the Westfield River downstream of the dam. Flows would pass over the existing concrete weir (which maintains the pool at elevation 518 feet NGVD) and discharge through the flood control outlet works where they would be diverted to a penstock via a proposed bifurcation/regulation structure at the outlet of the existing flood control conduit. When the plant is generating, the downstream flood control gates at the regulation structure will be closed with all flow passing through the powerhouse. During high flow periods or times of flood storage releases, the units will operate at installed capacity. Should flows in excess of power plant capacity occur, it would be possible, within limits, to discharge through both the turbine for generation as well as through the flood control gates, but with some loss in net power head and generating capacity. During periods of flood regulation the turbines would be throttled as necessary and flow releases made through the flood control gates. If the pool drops below elevation 518, generation would cease as water would not be flowing over the concrete weir, and would therefore not be available. Hydropower generation would be preempted as required for flood regulation. As in alternative 1, it is expected that the project under alternative 2, would operate mostly at design capacity through March, April and May due to the availability of high flows and would probably operate intermittently during the historic low flow periods of July through October.

The penstock in alternative 2 is independent of the existing water supply conduit and during water supply releases, simultaneous releases through the penstock for generation could be possible provided the pool elevation is not below 518.

WATER SUPPLY SENSITIVITY ANALYSIS

General

A hydrologic analysis was performed to assess the impact of possible future water supply diversions at Littleville Dam on its average annual hydropower potential. Though presently not used, the Littleville project storage to elevation 518 feet NGVD is designed to supplement the existing water supply system of the city of Springfield, Massachusetts.

Hydrologic Analysis

The operation of Cobble Mountain and Littleville was simulated, with the aid of computer program "HEC-3", as a twin reservoir system operating in concert to meet a single water supply demand.

When drawing from reservoir storage, for water supply, Cobble Mountain was drafted first until it reached a storage per unit drainage area comparable to the total water supply storage at Littleville per unit area. Once drafted to that level the two reservoirs were then drafted together as required. The projects were given similar priorities for refill, but Cobble Mountain was given some priority to remain somewhat less than full, except during spring refill (March-May), thus preventing frequent spillage at Cobble Mountain at the expense of later loss of hydropower flows at Littleville. The analysis, using 70 years of historic flow records, indicated that Cobble Mountain alone had a maximum dependable yield of about 67 cfs (44 MGD), whereas, the two projects as a system had a combined safe yield of 107 cfs, (70 MGD). The projects were simulated and the average annual spillage at Littleville determined for a range of system yields.

The hydropower at Littleville would be dependent on the excess flows at Littleville, therefore, approximate hydropower potential versus water supply demand was determined for a range of installed capacities. Hydropower potential estimates were determined by adjusting the natural flow duration curve at Littleville for the relative reduction in average annual spillage due to water supply. It was determined that the hydropower potential at Littleville could be reduced as much as 50 percent if the project was operated in concert with Cobble Mountain for a maximum combined water supply yield of 70 MGD. Approximate relations between hydropower potential, installed capacity, and system water supply yield are illustrated on plate A-17.

CORPS OF ENGINEERS U. S. ARMY

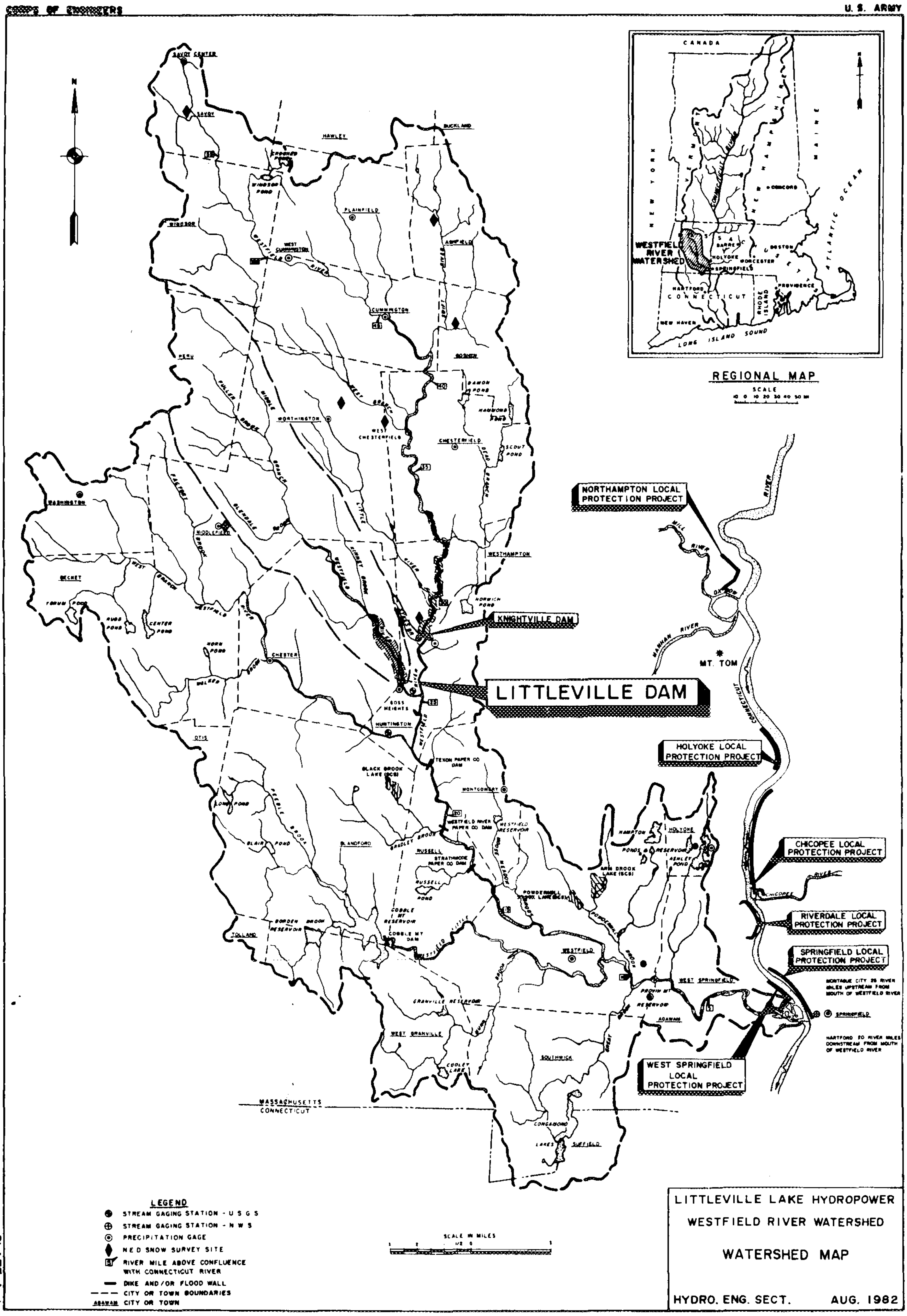
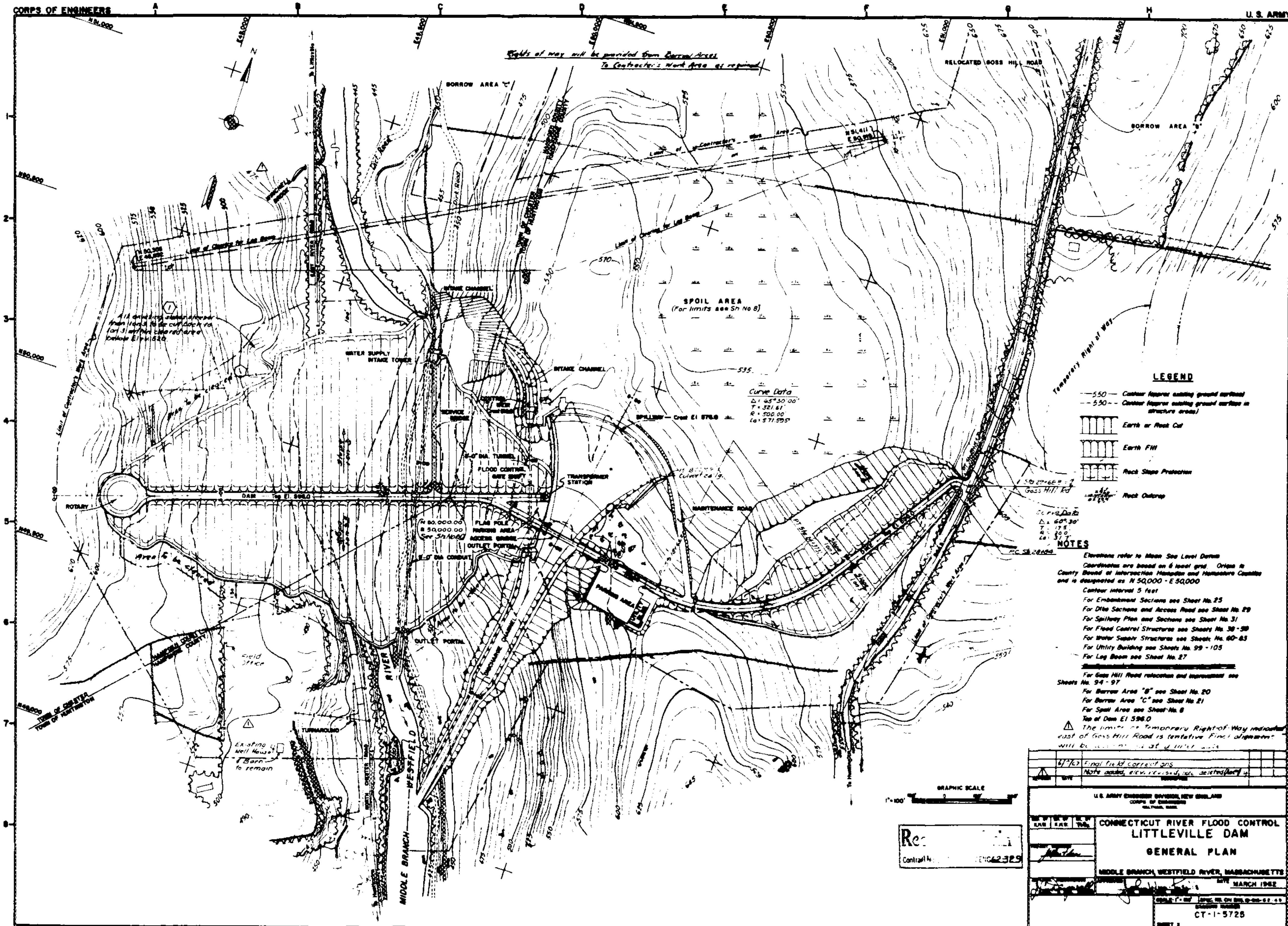
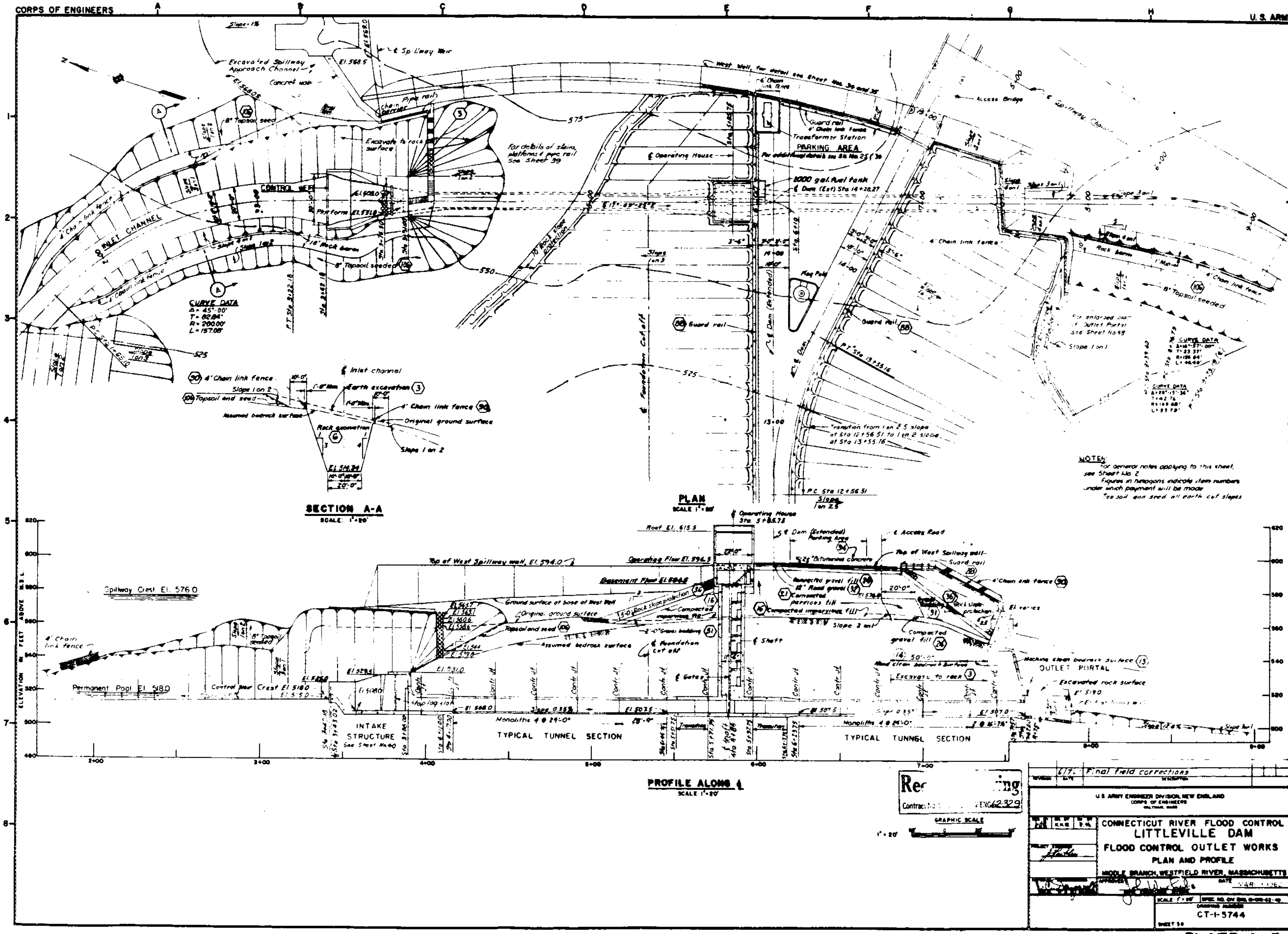


PLATE A-1



CORPS OF ENGINEERS
U.S. ARMY
Rights of way will be provided from Borrow Areas To Contractor's Work Area as required
BORROW AREA "C"
RELOCATED GOSS HILL ROAD
BORROW AREA "B"
SPOIL AREA
(For limits see Sh No 8)
SPILLWAY CHANNEL
WATER SUPPLY INTAKE TOWER
INTAKE CHANNEL
SERVICE BRIDGE
FLOOD CONTROL GATE SHAFT
TRANSFORMER STATION
ROTARY
DAM Top El 596.0
FLAG POLE
PARKING AREA
OUTLET PORTAL
MAINTENANCE ROAD
TURNAROUND
MIDDLE BRANCH — WESTFIELD RIVER
Temporary Right of Way
LEGEND
Contour (approx existing ground surface)
Contour (approx existing ground surface in structure areas)
Earth or Rock Cut
Earth Fill
Rock Slope Protection
Rock Outcrop
NOTES
Elevations refer to Mean Sea Level Datum
Coordinates are based on a local grid. Origin is County Bound at intersection Hampden and Hampshire Counties and is designated as N 50,000 - E 50,000
Contour interval 5 feet
For Embankment Sections see Sheet No. 25
For Dike Sections and Access Road see Sheet No. 29
For Spillway Plan and Sections see Sheet No. 31
For Flood Control Structures see Sheets No. 38 - 59
For Water Supply Structures see Sheets No. 60 - 63
For Utility Building see Sheets No. 99 - 105
For Log Boom see Sheet No. 27
For Goss Hill Road relocation and improvement see Sheets No. 94 - 97
For Borrow Area "B" see Sheet No. 20
For Borrow Area "C" see Sheet No. 21
For Spoil Area see Sheet No. 8
Top of Dam El 596.0
Final field corrections
GRAPHIC SCALE
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
GENERAL PLAN
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
MARCH 1962
CT-1-5725

PLATE A-2



CORPS OF ENGINEERS
U.S. ARMY
INLET CHANNEL
CONTROL WEIR
PARKING AREA
1000 gal. fuel tank
CURVE DATA
Δ = 45°-00'
T = 82.84'
R = 200.00'
L = 157.08'
SECTION A-A
SCALE: 1" = 20'
PLAN
NOTES:
For general notes applying to this sheet, see Sheet No. 2
Figures in hexagons indicate item numbers under which payment will be made
Top soil and seed all earth cut slopes
Spillway Crest El. 576.0
Permanent Pool El. 518.0
Top of West Spillway wall, El. 594.0
Operating Floor El. 596.5
INTAKE STRUCTURE
TYPICAL TUNNEL SECTION
OUTLET PORTAL
ELEVATION IN FEET ABOVE M.S.L.
PROFILE ALONG ℄
SCALE 1" = 20'
GRAPHIC SCALE
Final field corrections
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
FLOOD CONTROL OUTLET WORKS
PLAN AND PROFILE
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
CT-1-5744

PLATE A-3

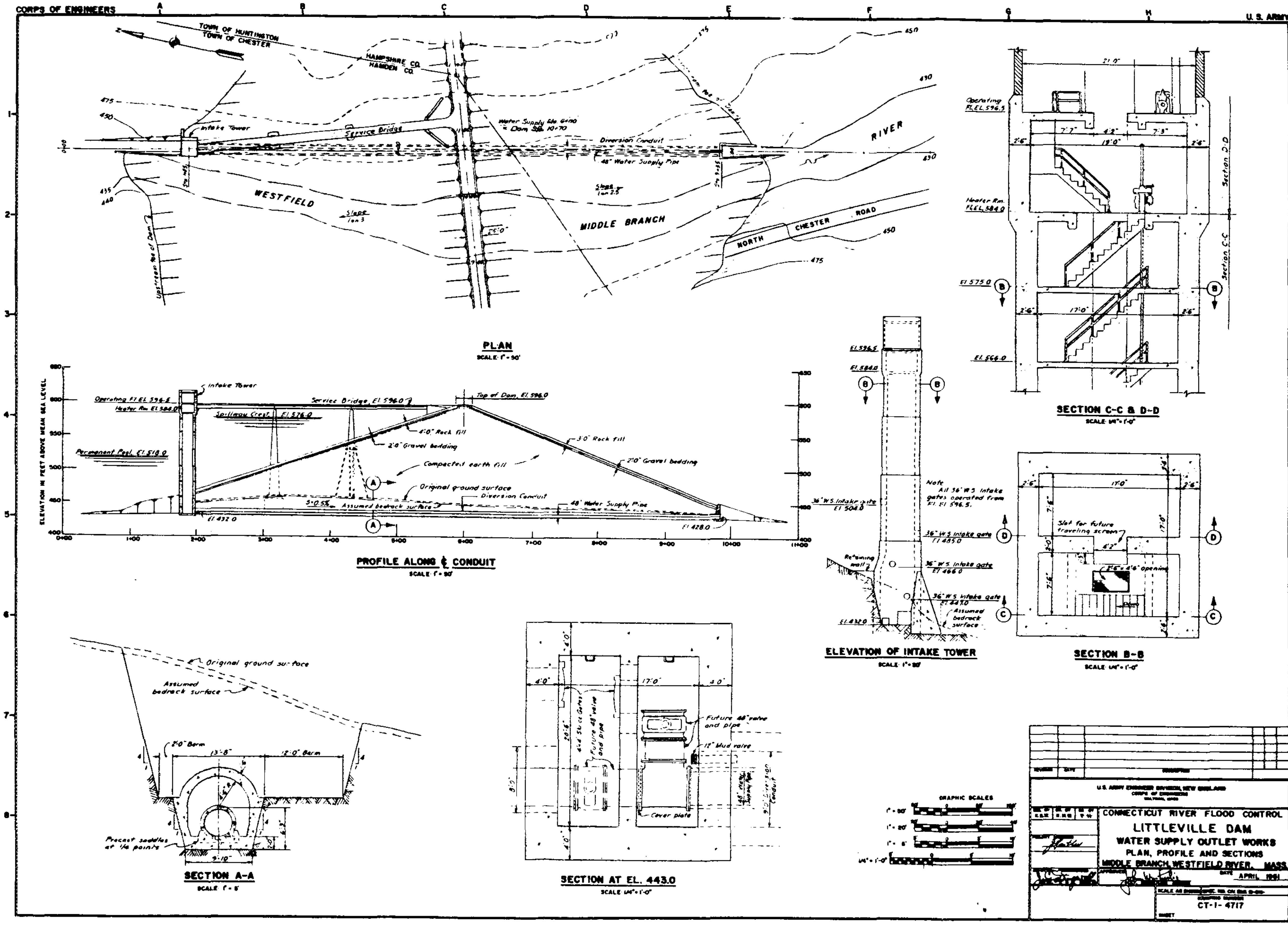
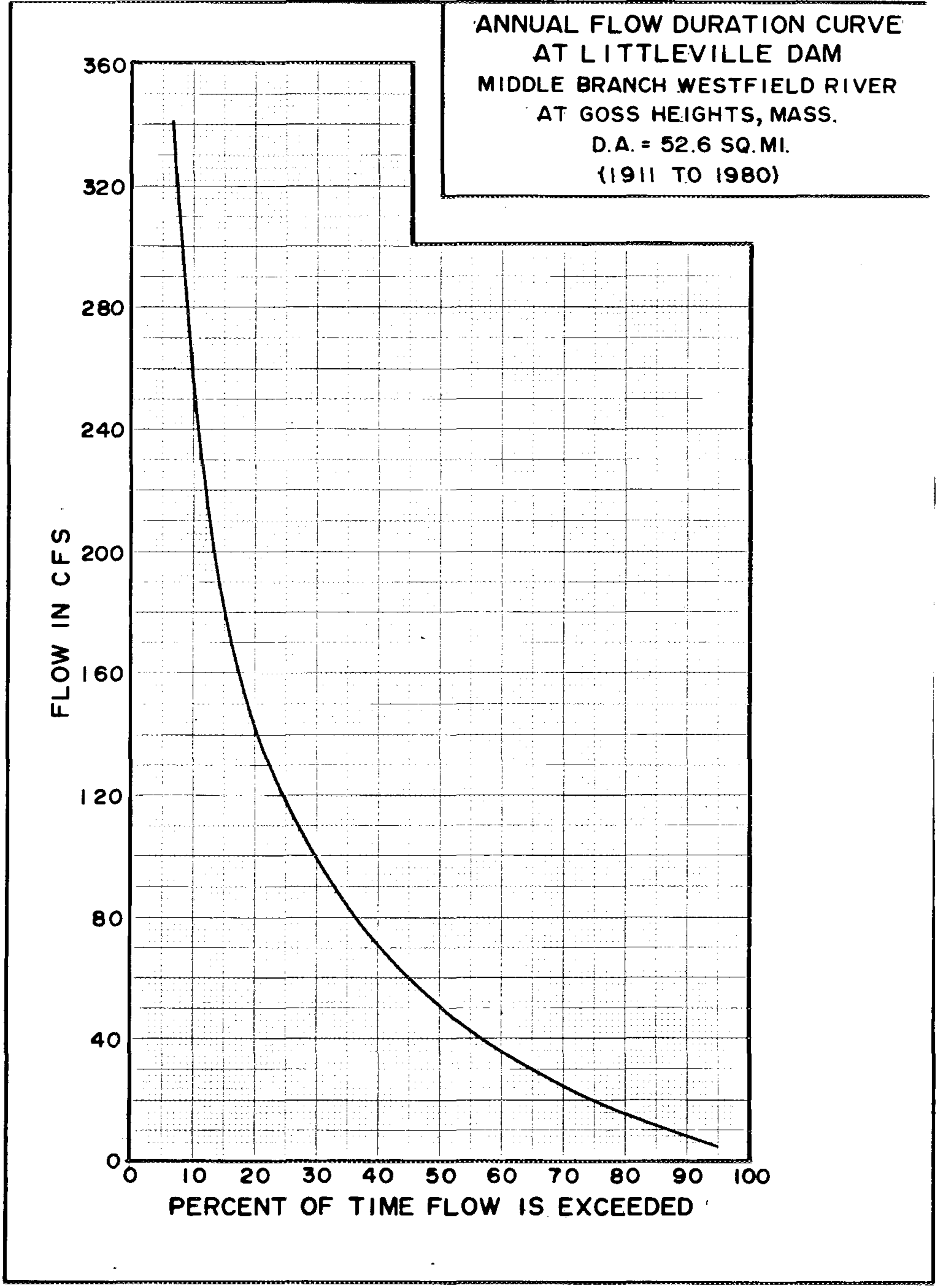
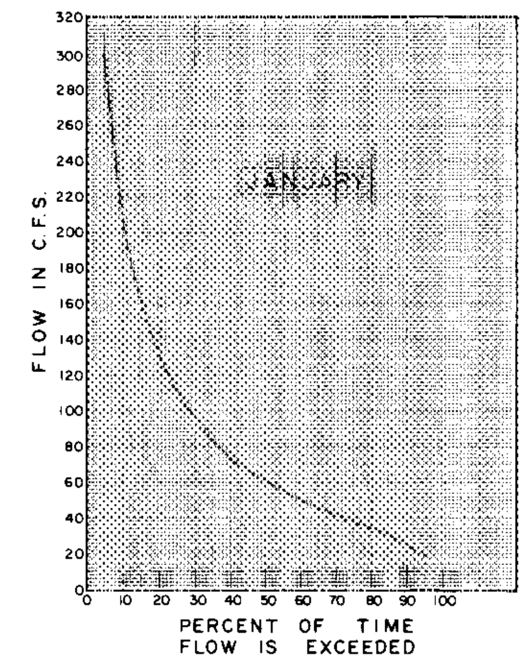
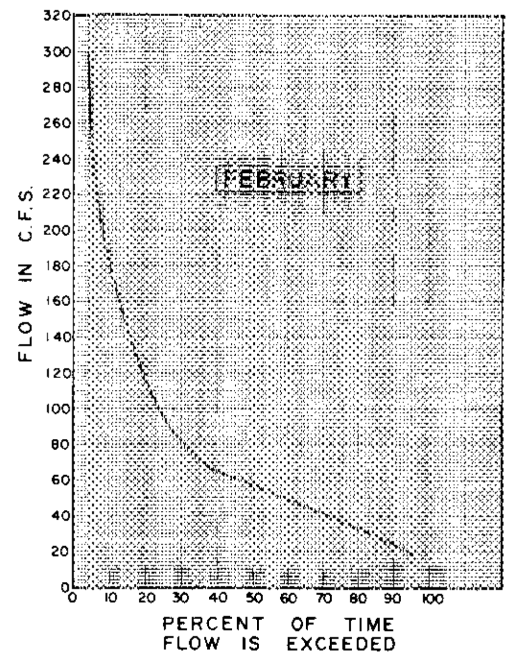

CORPS OF ENGINEERS
U.S. ARMY
TOWN OF HUNTINGTON
TOWN OF CHESTER
HAMPSHIRE CO.
HAMDEN CO.
Intake Tower
Service Bridge
Diversion Conduit
48" Water Supply Pipe
WESTFIELD
MIDDLE BRANCH
RIVER
NORTH CHESTER ROAD
PLAN
SCALE: 1" = 50'
Intake Tower
Operating Fl. El. 596.5
Heater Rm. El. 584.0
Service Bridge, El. 596.0
Top of Dam, El. 596.0
Spillway Crest, El. 576.0
Permanent Pool, El. 518.0
4'-0" Rock fill
2'-0" Gravel bedding
3'-0" Rock fill
Compacted earth fill
Original ground surface
Diversion Conduit
48" Water Supply Pipe
Assumed bedrock surface
El. 432.0
El. 428.0
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
PROFILE ALONG ℄ CONDUIT
SCALE: 1" = 50'
ELEVATION OF INTAKE TOWER
SCALE: 1" = 20'
Note: All 36" W.S. intake gates operated from Fl. El. 596.5.
SECTION C-C & D-D
SCALE: 1/4" = 1'-0"
SECTION B-B
SCALE: 1/4" = 1'-0"
Slot for future traveling screen
Original ground surface
Assumed bedrock surface
2'-0" Berm
12'-0" Berm
Precast saddles at 1/4 points
SECTION A-A
SCALE: 1" = 5'
Future 48" valve and pipe
12" Mud valve
Cover plate
SECTION AT EL. 443.0
SCALE: 1/4" = 1'-0"
GRAPHIC SCALES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
WATER SUPPLY OUTLET WORKS
PLAN, PROFILE AND SECTIONS
MIDDLE BRANCH WESTFIELD RIVER, MASS.
APRIL 1961
CT-1-4717

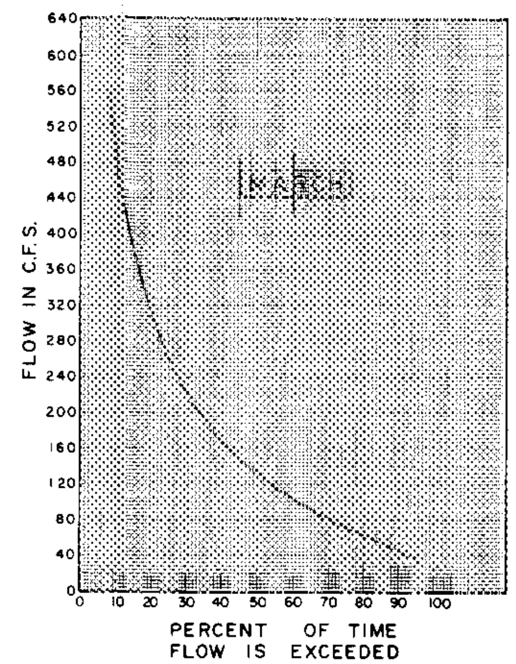
PLATE A-4

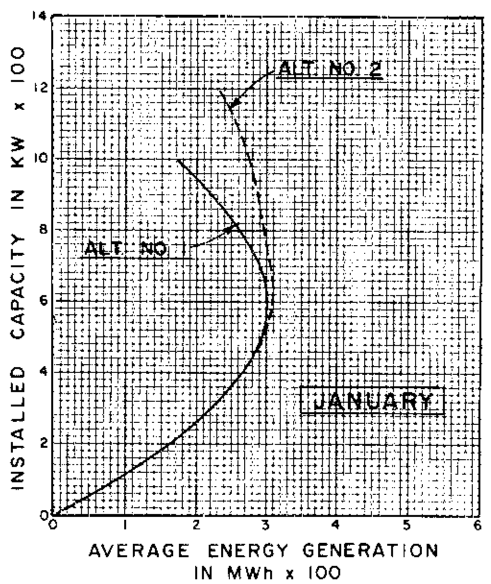


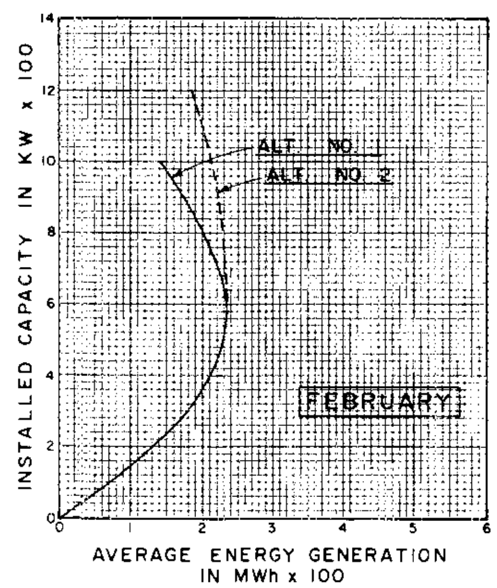
ANNUAL FLOW DURATION CURVE
AT LITTLEVILLE DAM
MIDDLE BRANCH WESTFIELD RIVER
AT GOSS HEIGHTS, MASS.
D.A. = 52.6 SQ. MI.
(1911 TO 1980)
FLOW IN CFS
360
320
280
240
200
160
120
80
40
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT OF TIME FLOW IS EXCEEDED

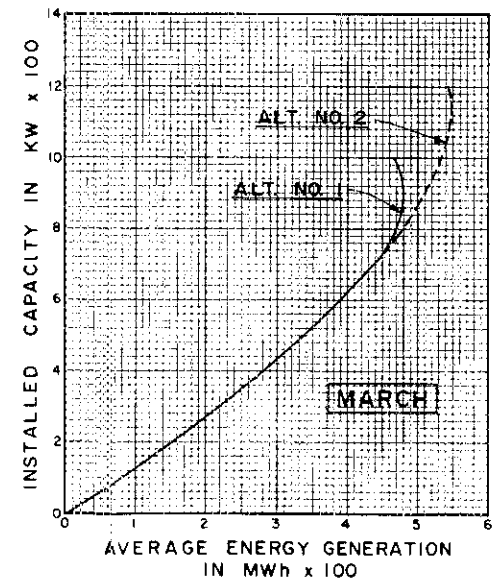












ALTERNATIVE NO. 1 = 4.0' DIAMETER PENSTOCK

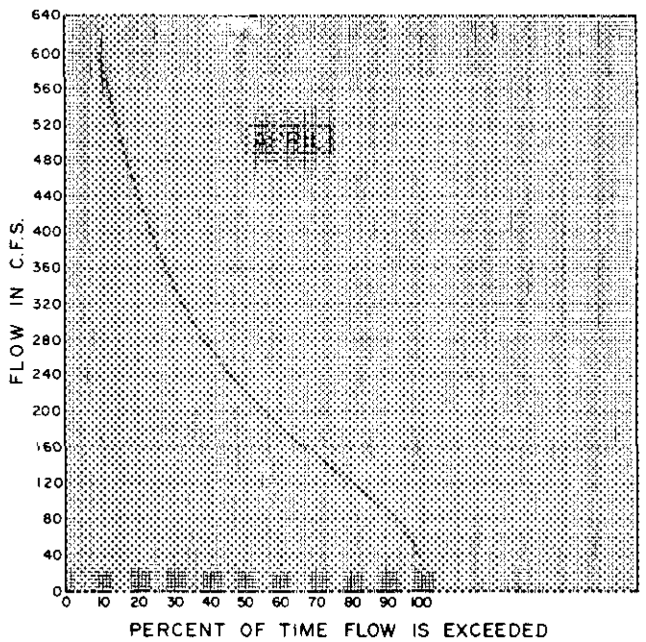
ALTERNATIVE NO. 2 = 5.0' DIAMETER PENSTOCK

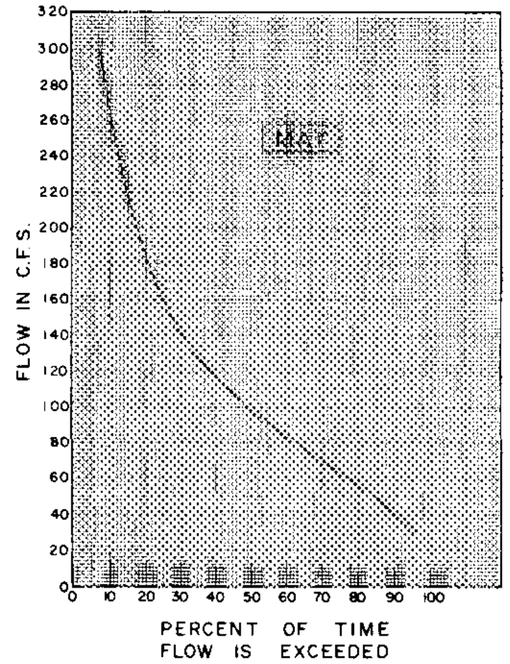
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

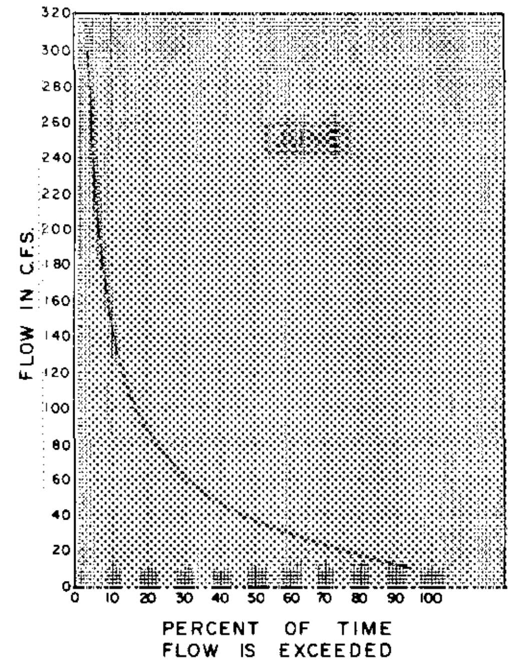
LITTLEVILLE LAKE HYDROPOWER

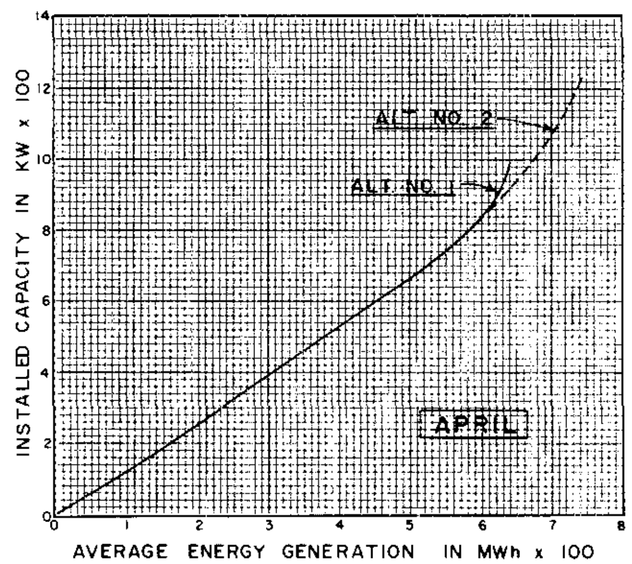
MONTHLY FLOW DURATION CURVES AND AVERAGE MONTHLY ENERGY

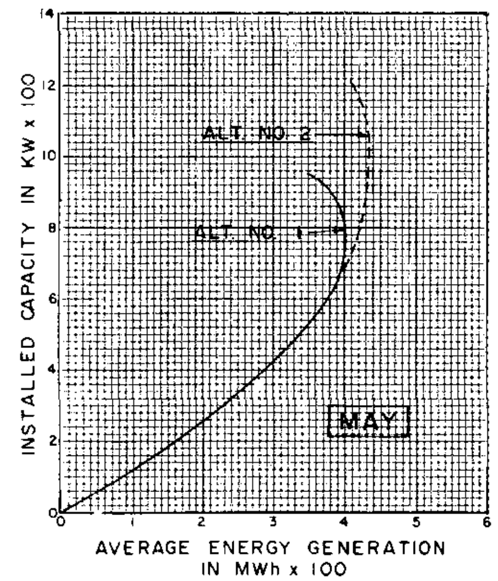
HYDRO. ENG. SECT. AUGUST 1982

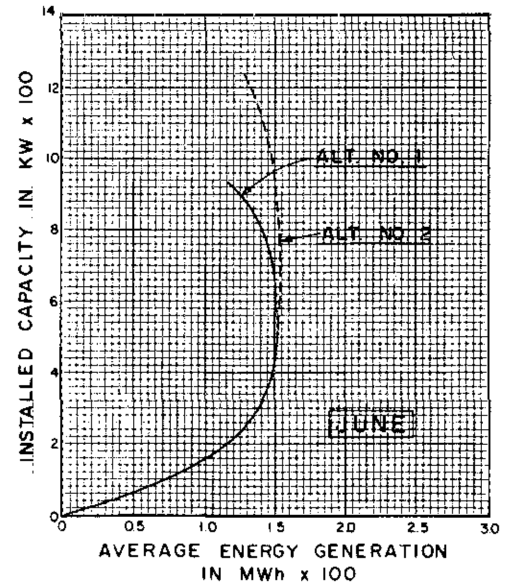












ALTERNATIVE NO. 1 = 4.0 DIAMETER PENSTOCK

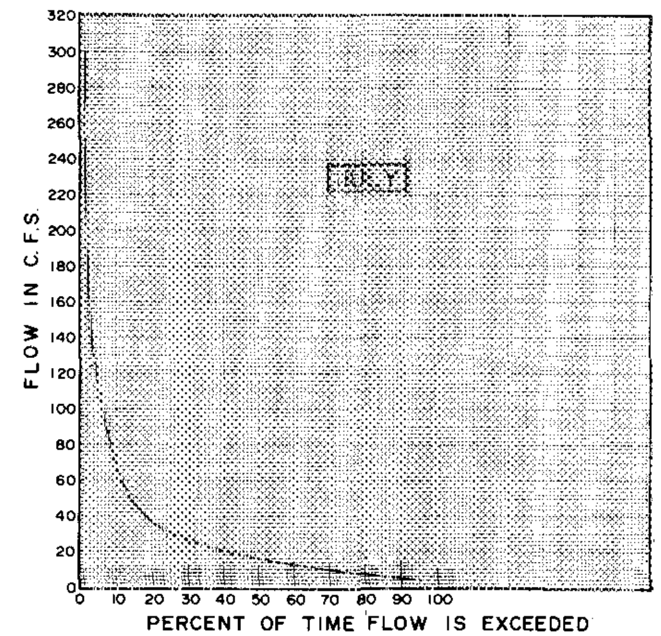
ALTERNATIVE NO. 2 = 5.0 DIAMETER PENSTOCK

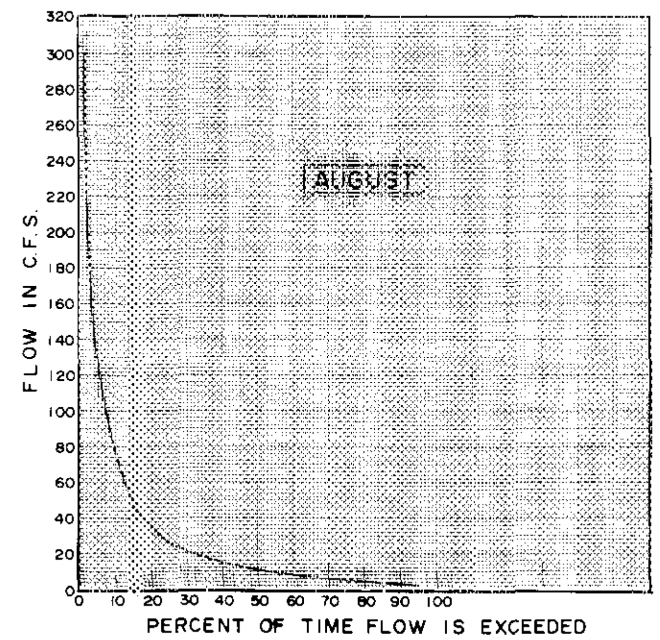
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

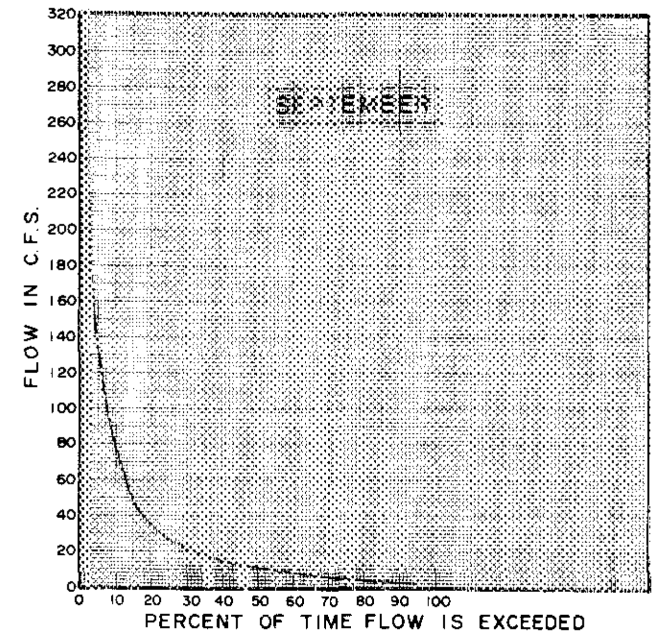
LITTLEVILLE LAKE HYDROPOWER

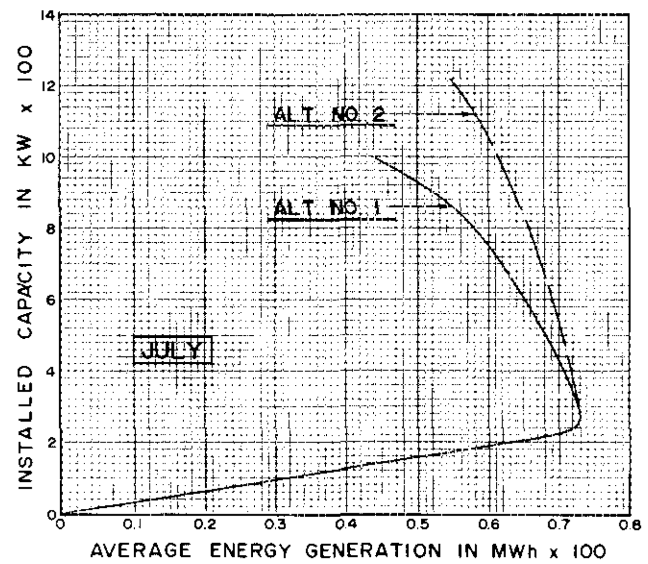
MONTHLY FLOW DURATION CURVES
AND
AVERAGE MONTHLY ENERGY

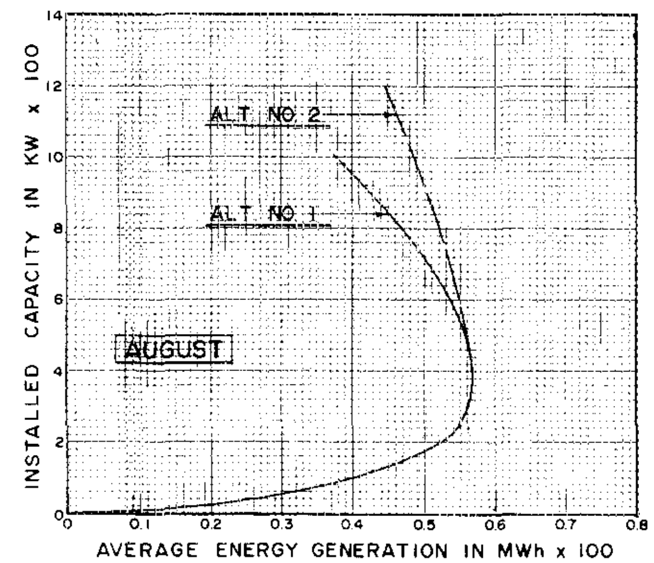
HYDRO. ENG. SECT. AUGUST 1982

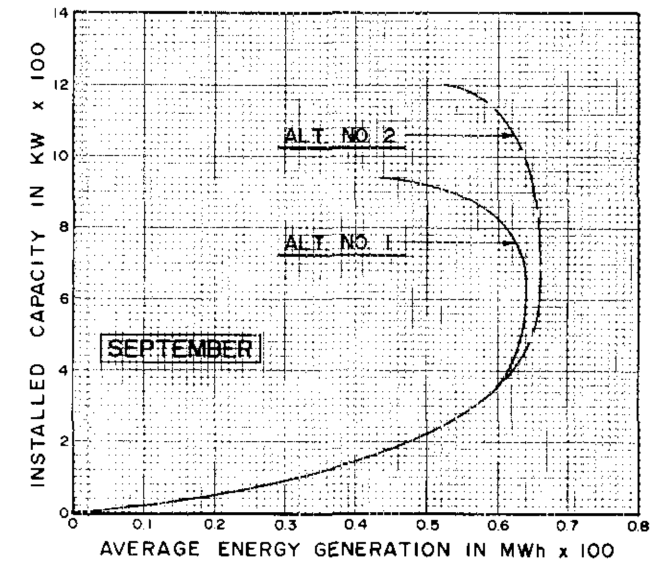












ALTERNATIVE NO. 1 = 4.0' DIAMETER PENSTOCK

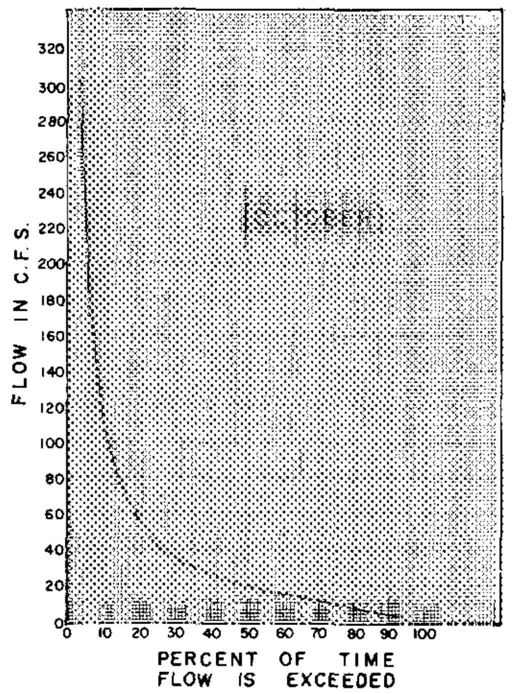
ALTERNATIVE NO. 2 = 5.0' DIAMETER PENSTOCK

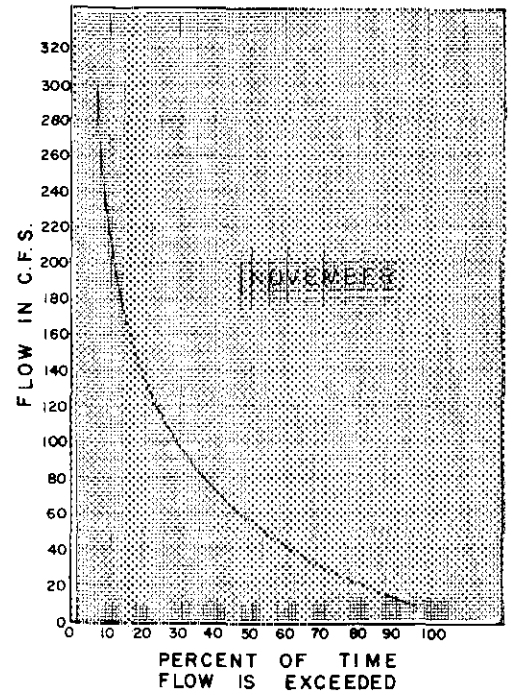
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

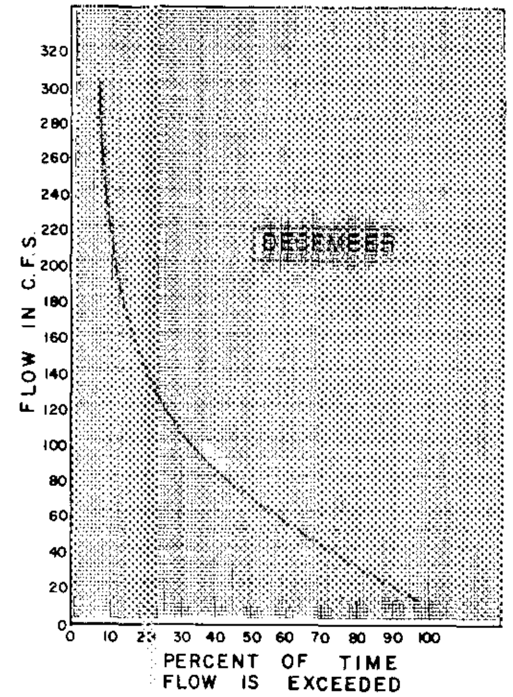
LITTLEVILLE LAKE HYDROPOWER

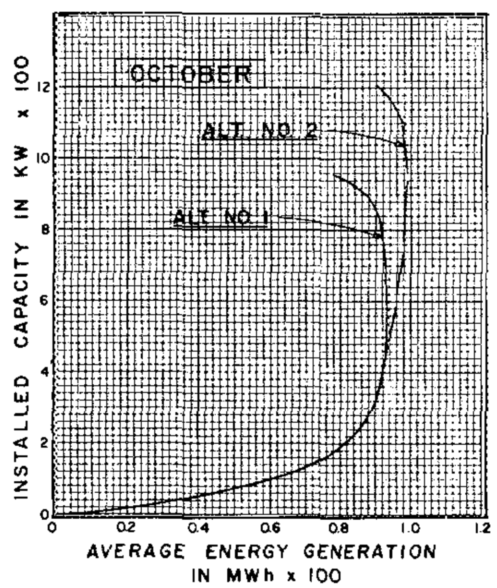
MONTHLY FLOW DURATION CURVES
AND
AVERAGE MONTHLY ENERGY

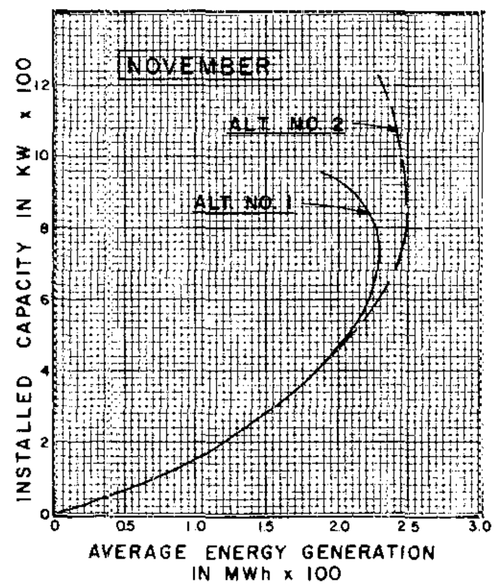
HYDRO. ENG. SECT. AUGUST 1982

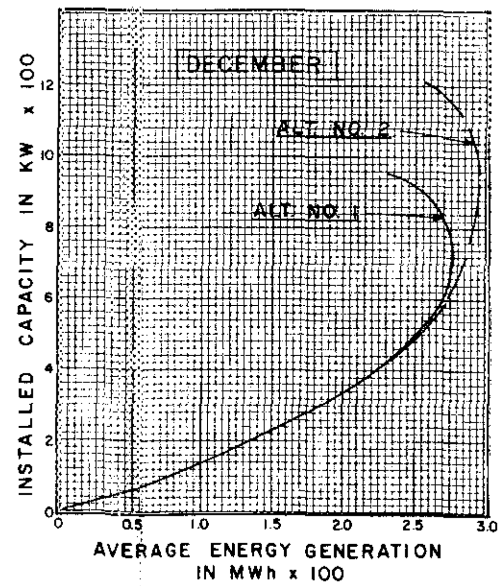












ALTERNATIVE NO. 1 = 4.0' DIAMETER PENSTOCK

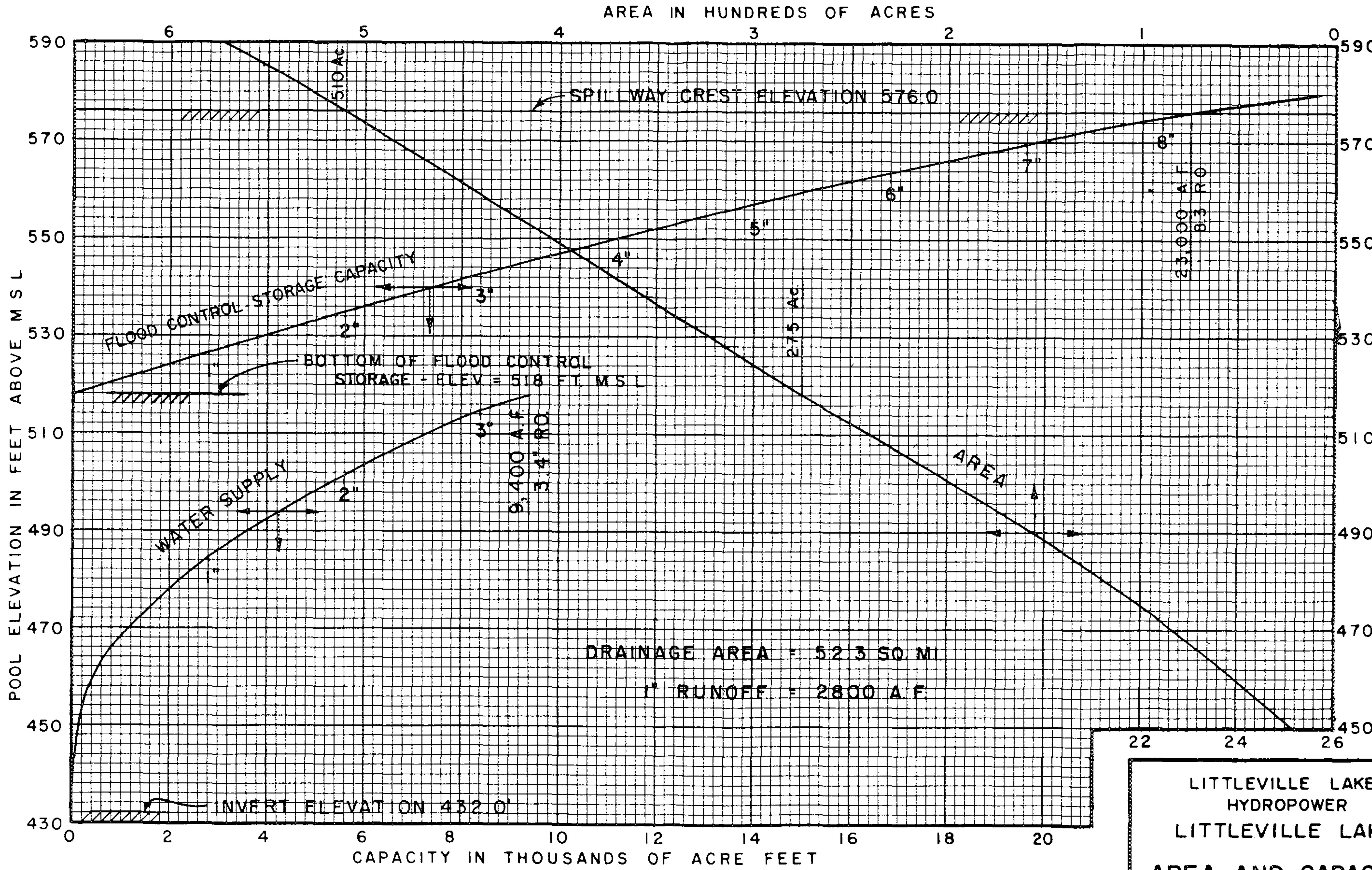
ALTERNATIVE NO. 2 = 5.0' DIAMETER PENSTOCK

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

LITTLEVILLE LAKE HYDROPOWER

MONTHLY FLOW DURATION CURVES
AND
AVERAGE MONTHLY ENERGY

HYDRO. ENG. SECT. AUGUST 1982

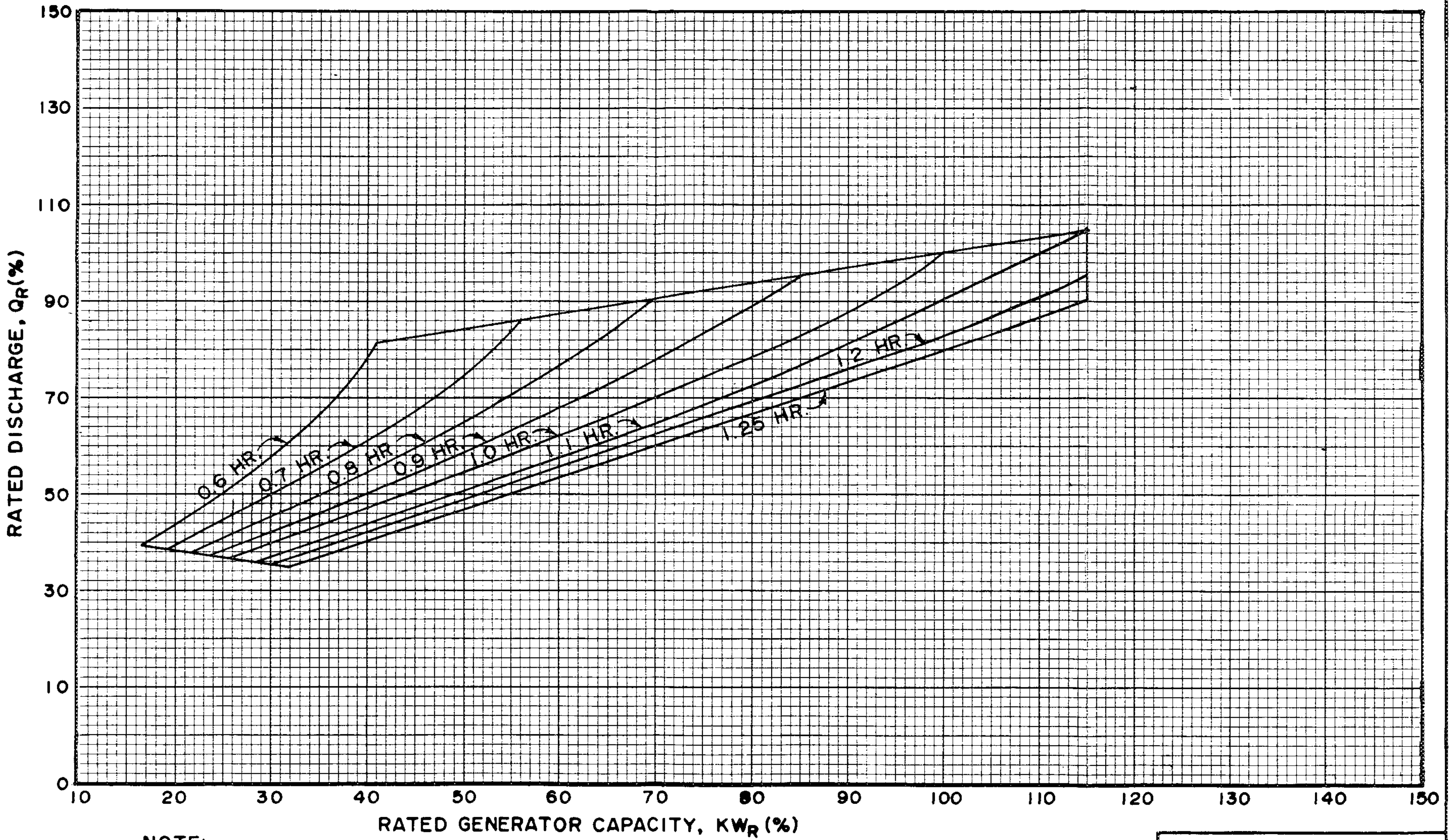


LITTLEVILLE LAKE
HYDROPOWER
LITTLEVILLE LAKE

AREA AND CAPACITY CURVE

HYDRO. ENG. SECT   AUG. 1982

PLATE A-10



NOTE:

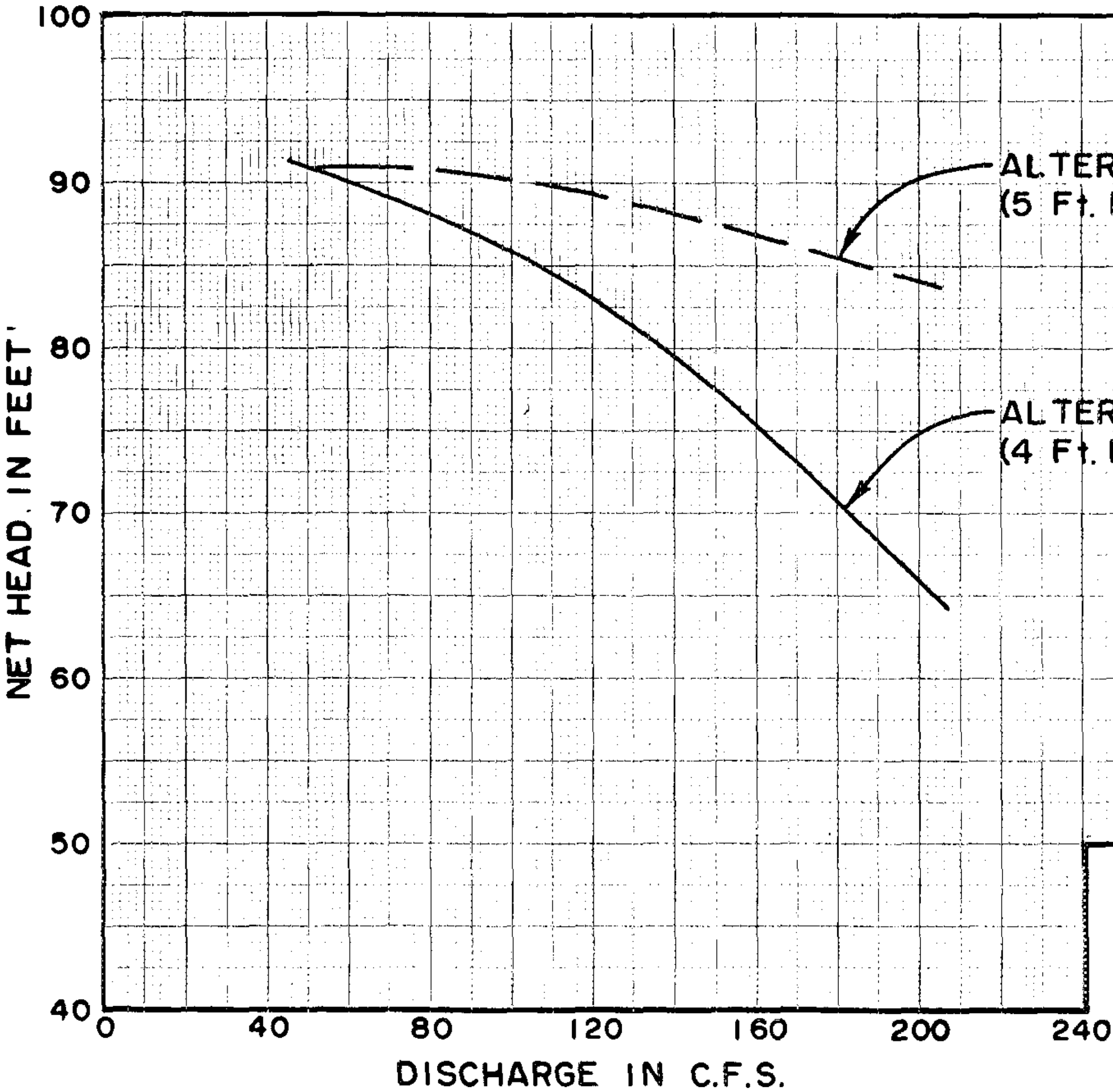
TAKEN FROM "FEASIBILITY STUDIES FOR SMALL SCALE HYDROPOWER ADDITIONS - A GUIDE MANUAL," JULY 1979.

LITTLEVILLE LAKE
HYDROPOWER

TURBINE PERFORMANCE CURVES

HYDRO. ENG. SECT. AUG. 1982

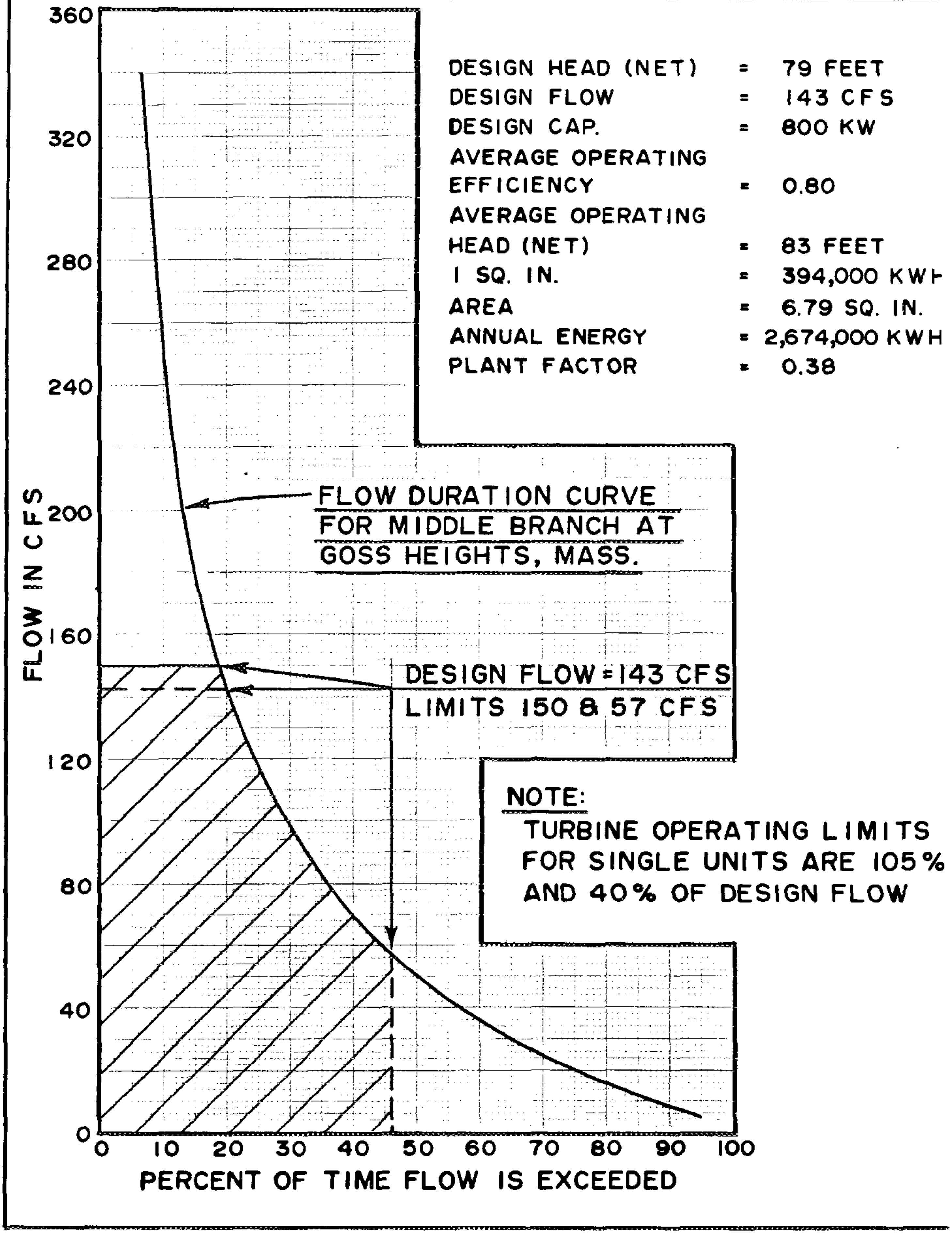
PLATE A-11



LITTLEVILLE LAKE
HYDROPOWER
NET HEAD
VS.
DISCHARGE

HYDRO ENG SECT AUG 198

EXAMPLE OF AVERAGE ANNUAL ENERGY COMPUTATION



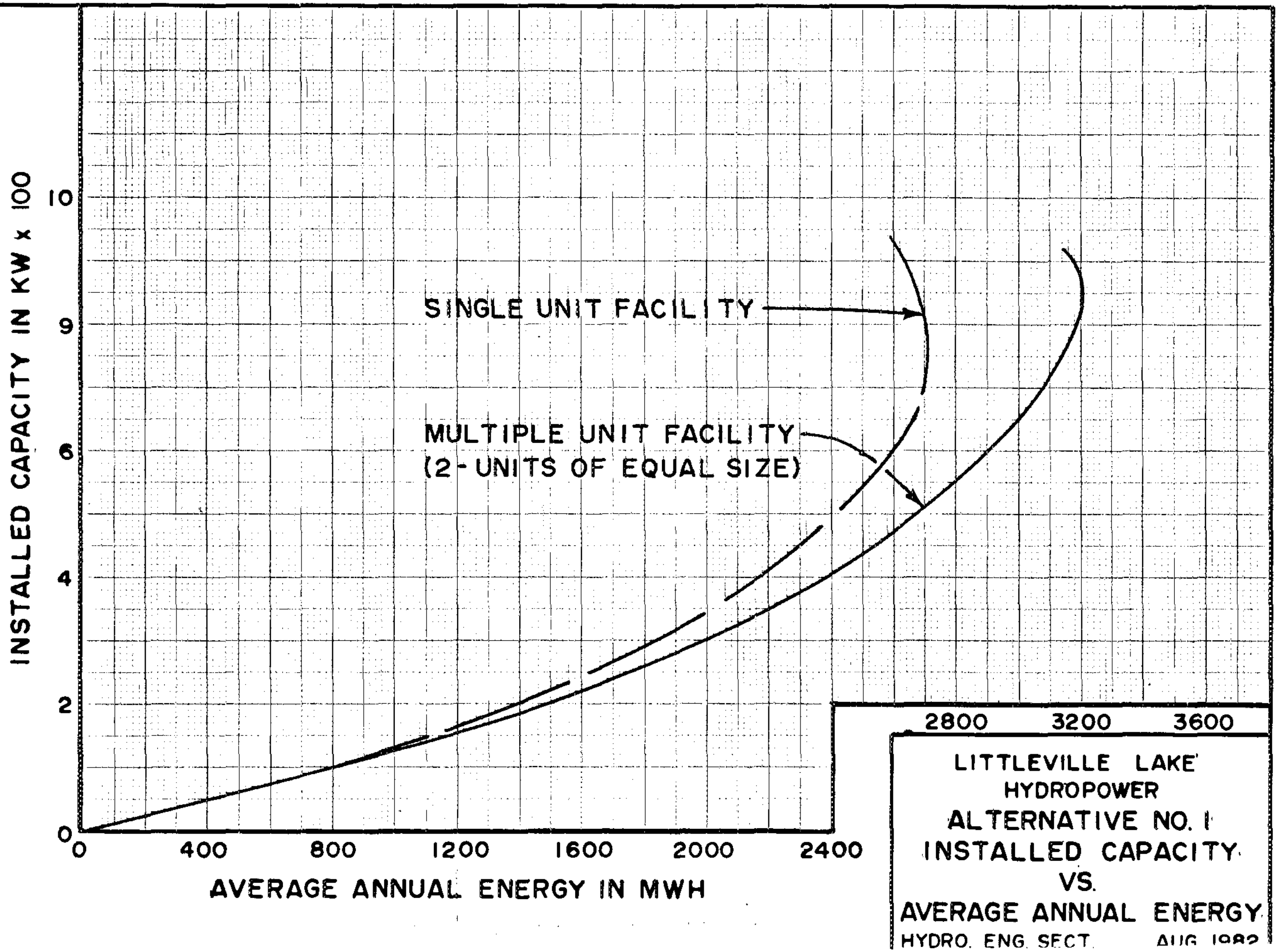
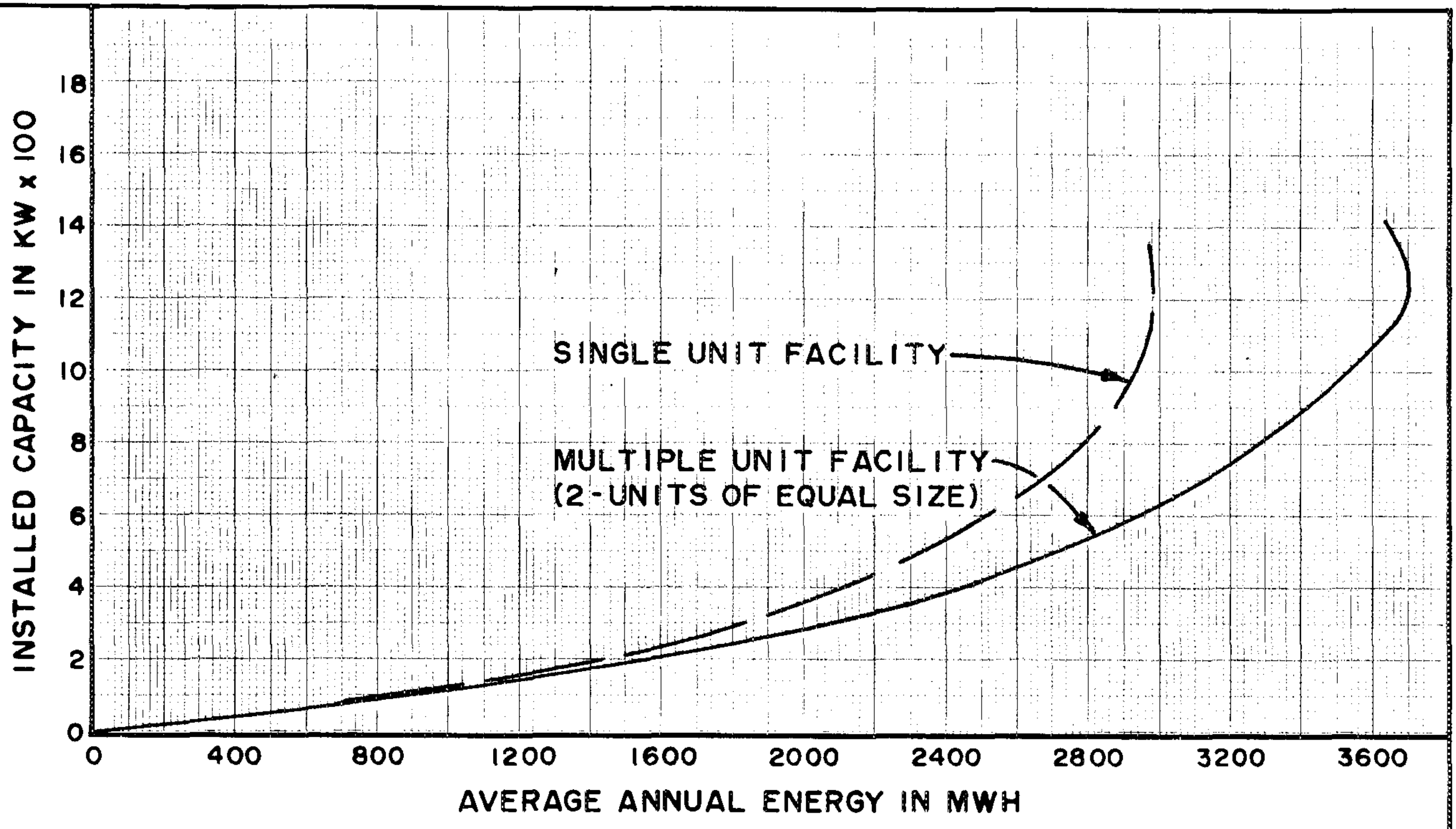
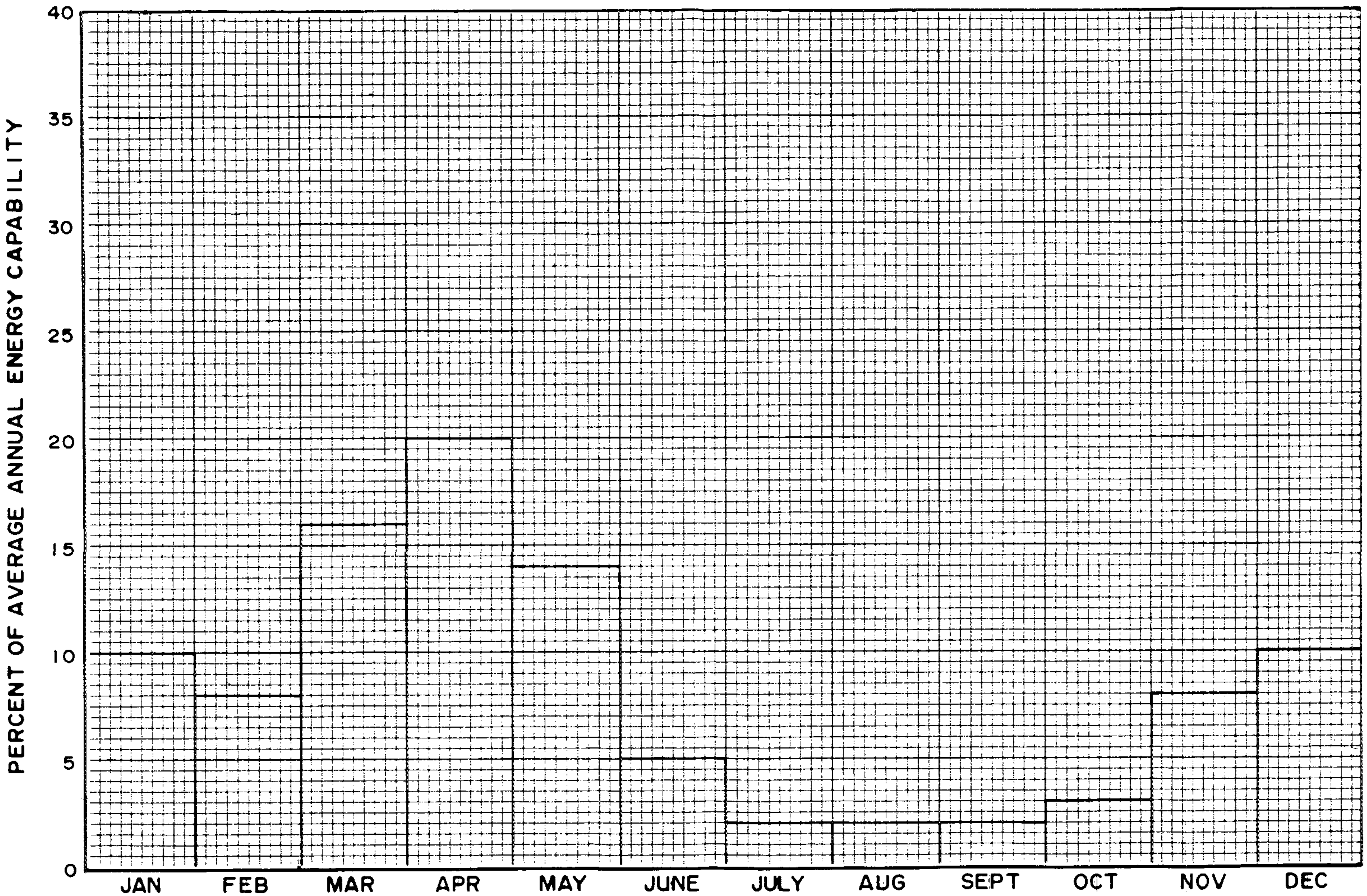

INSTALLED CAPACITY IN KW x 100
AVERAGE ANNUAL ENERGY IN MWH
SINGLE UNIT FACILITY
MULTIPLE UNIT FACILITY
(2-UNITS OF EQUAL SIZE)
0
2
4
6
9
10
0
400
800
1200
1600
2000
2400
2800
3200
3600
LITTLEVILLE LAKE
HYDROPOWER
ALTERNATIVE NO. 1
INSTALLED CAPACITY
VS.
AVERAGE ANNUAL ENERGY
HYDRO. ENG. SECT.
AUG. 1982

PLATE A-14



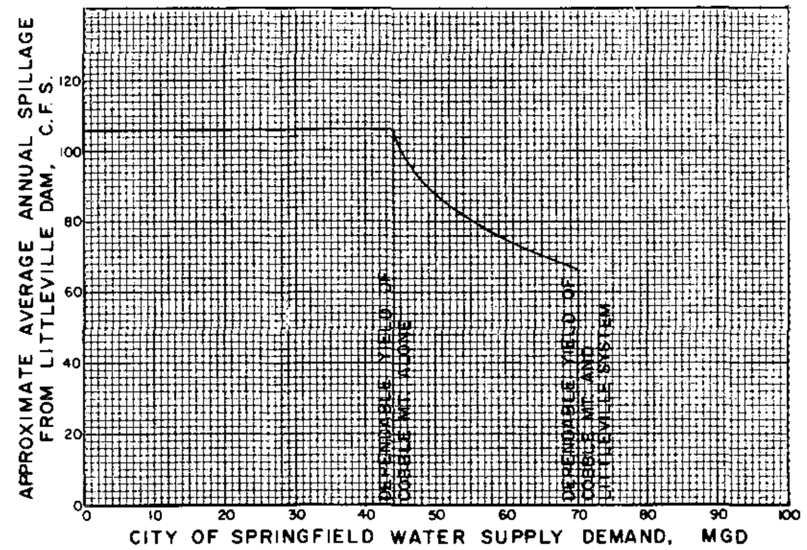
LITTLEVILLE LAKE
HYDROPOWER
ALTERNATIVE NO. 2
INSTALLED CAPACITY
VS.
AVERAGE ANNUAL ENERGY
HYDRO. ENG. SECT. AUG. 1982



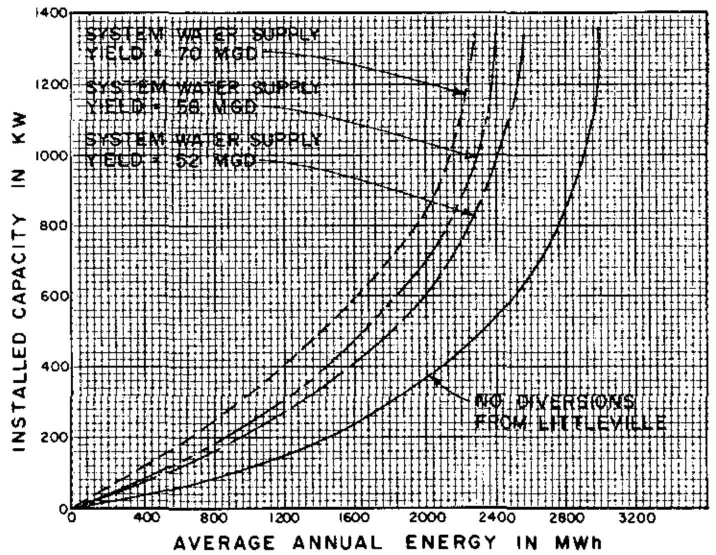
LITTLEVILLE LAKE
HYDROPOWER

MONTHLY GENERATING PATTERN IN PERCENT OF ANNUAL CAPABILITY

HYDRO. ENG. SECT. AUG. 1982

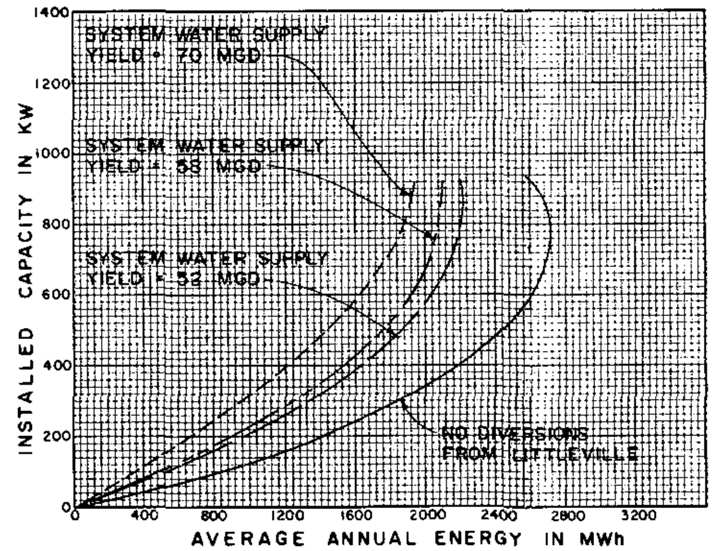


APPROXIMATE AVERAGE ANNUAL SPILLAGE FROM LITTLEVILLE DAM VS. WATER SUPPLY DEMAND ON COBBLE MT. & LITTLEVILLE SYSTEM



ALTERNATIVE NO. 1

HYDROPOTENTIAL AT LITTLEVILLE DAM VS. WATER SUPPLY YIELD FROM COBBLE MT. AND LITTLEVILLE SYSTEM (SINGLE UNIT ONLY)



ALTERNATIVE NO. 2

HYDROPOTENTIAL AT LITTLEVILLE DAM VS. WATER SUPPLY YIELD FROM COBBLE MT. AND LITTLEVILLE SYSTEM (SINGLE UNIT ONLY)

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

LITTLEVILLE LAKE HYDROPOWER

EFFECT OF SYSTEM WATER SUPPLY YIELD ON THE HYDROPOTENTIAL AT LITTLEVILLE DAM

HYDRO. ENG. SECTION AUGUST 1982

LITTLEVILLE LAKE HYDROPOWER
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LITTLEVILLE LAKE HYDROPOWER
APPENDIX B
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INTRODUCTION

The purpose of this study is to evaluate the effects of alternative hydropower development schemes on water quality conditions in Littleville Lake and its immediate downstream impact area, and to investigate the need for modification of the present outlet works to provide water quality enhancement through the addition of multiple level outlet capabilities in accordance with ER 1110-2-1410. A comprehensive evaluation of existing water quality conditions is presented, and predictions of impact related to project implementation based on a reservoir temperature modeling analysis are made. A generalized version of the Corps WESTEX reservoir heat budget model, incorporating state-of-the-art capabilities in 1-dimensional lake modeling, was developed for this study by the Waterways Experiment Station (WES).

The predictive studies reported herein were carried out for two alternatives which would use essentially the same run-of-river operation but with different outlet works and penstocks: (a) alternative 1 will use the existing 48-inch water supply line with its existing multilevel orifice intake structure, and (b) alternative 2 will use the existing high level flood control conduit with its existing weir controlled intake structure.

EXISTING WATER QUALITY

Classification

From its headwaters to the its confluence with the Westfield River, the Middle Branch of the Westfield River has been assigned two water quality classifications. The portion located upstream from Littleville Dam has been designated by the Massachusetts Water Resources Commission (MWRC) as class A and the portion downstream from the dam, a distance of 1 mile, has been designated a class B seasonal cold water fishery. The reach of the Westfield River, from its confluence with the Middle Branch to the river's confluence with the Connecticut River, has been designated as a class B warm water fishery. Class A waters are designated for use as a source of public water supply and class B waters are designated for protection and propagation of fish, other aquatic life and wildlife and for primary and secondary contact recreation. A seasonal cold water fishery is capable of sustaining a population of trout (salmonidae) from 15 September through 30 June only, while during the rest of the year, the criteria of a warm water fishery apply. A summary of the requirements for class A and B waters is included in table B-1.

TABLE B-1

WATER QUALITY STREAM CLASSIFICATION FOR MASSACHUSETTS

MASSACHUSETTS STREAM CLASSIFICATION CRITERIA

These minimum criteria are applicable to all waters of Massachusetts unless criteria specified for individual classes are more stringent.

Parameter	Criteria
1. Aesthetics	All waters shall be free from pollutants in concentrations or combinations that: a. Settle to form objectionable deposits. b. Float as debris, scum or other matter to form nuisances. c. Produce objectionable odor, color, taste or turbidity. d. Result in the dominance of nuisance species.
2. Radioactive Substances	Shall not exceed the recommended limits of the United States Environmental Protection Agency's National Drinking Water Regulations.
3. Tainting Substances	Shall not be in concentrations or combinations that produce undesirable flavors in the edible portions of aquatic organisms.
4. Color, Turbidity, Total Suspended Solids	Shall not be in concentrations or combinations that would exceed the recommended limits on the most sensitive receiving water use.
5. Oil and Grease	The water surface shall be free from floating oils, grease and petrochemicals and any concentrations or combinations in the water column or sediments that are aesthetically objectionable or

Parameter	Criteria
5. Oil and Grease (continued)	deleterious to the biota are prohibited. For oil and grease of petroleum origin the maximum allowable discharge concentration is 15 mg/l.
6. Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
7. Other Constituents	Waters shall be free from pollutants in concentrations or combinations that: a. Exceed the recommended limits on the most sensitive receiving water use. b. Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life. c. Exceed site-specific safe exposure levels determined by bioassay using sensitive resident species.

MASSACHUSETTS CLASS A WATERS

Waters assigned to this class are designated for use as a source of public water supply.

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83° F (28.3° C) in warm water fisheries or 68° F (20° C) in cold water fisheries nor shall the rise resulting from artificial origin exceed 4.0° F (2.2° C).
3. pH	As naturally occurs.
4. Total Coliform Bacteria	Shall not exceed a log mean for a set of samples of 50 per 100 ml during any monthly sampling period.
5. Turbidity	None other than of natural origin.

Parameter	Criteria
6. Total Dissolved Solids	Shall not exceed 500 mg/l.
7. Chlorides	Shall not exceed 250 mg/l.
8. Sulfates	Shall not exceed 250 mg/l.
9. Nitrate	Shall not exceed 10 mg/l as nitrogen.

MASSACHUSETTS CLASS B WATERS

Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation.

Parameter	Criteria
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83° F (28.3° C) in warm water fisheries or 68° F (20° C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0° F (2.2° C).
3. pH	Shall be in the range of 6.5 - 8.0 standard units and not more than 0.2 unit outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 200 per 100 ml, nor shall more than 10 percent of the total samples exceed 400 per 100 ml during any monthly sampling period.

Of the principle watersheds within the headwaters of the Westfield River basin the Middle Branch is the least accessible and least populated. Flow in the Middle Branch is generally fast moving and confined within a channel having no significant flood plain and a streambed consisting of rock, cobbles and gravel. As rpeorted by the MWRC, no pollution problems of any consequence are associated with this branch and its only uses by man are those of water supply (city of Springfield) and recreation.

Data Collection

Data have been collected on the Middle Branch in the area near Littleville on an intermittent basis by the MWRC and on a periodic basis since 1970 by the New England Division, Corps of Engineers (NED).

Due to the basin's rural nature, the MWRC has located only one sampling station on the Middle Branch. The one station sampled is located at the US Geological Survey streamflow gage at Goss Heights, approximately 0.7 mile downstream from the dam.

Under the Corps reservoir water quality control program, NED established two permanent stream sampling stations, LL01 and LL02 and 11 lake profile stations. Four temporary stream sampling stations(LL3A, LL3B, LL4A and LL4B) were established at the project for the purpose of this hydropower study during 1981. The permanent stream sampling stations have been periodically monitored on an annual basis since 1970. Sampling was performed at the temporary stream stations to ascertain the effects of reaeration processes on dissolved oxygen in the stream and to determine the water quality effects of the Middle Branch on the main stem of the Westfield River.

Water quality profile stations at Littleville Lake have been monitored during the years 1970, 1971, 1974, 1978, 1979 and 1981. Lake profile data were collected to determine the extent of thermally induced density stratification and its associated effects on overall water quality conditions within the impoundment. By combining these data with those for the inflow and outflow stations an analysis and evaluation of the impacts of the impoundment on downstream water quality can be made. The profile data collected during the period from 1970 through 1979 include the following parameters: temperature, dissolved oxygen, pH and conductivity and turbidity. Profile data collected specifically for this investigation in 1981 include the same parameters plus primary nutrients, color, residues, iron, manganese, and zinc. The latter were measured on an aperiodic basis during the year at the top, middle and bottom of the reservoir.

Stream Water Quality

The latest survey completed in 1978 by the MWRC showed that no violations of the class B Water Quality Standards were recorded and that dissolved oxygen concentration dipped below the 8.0 mg/l concentration only once. According to the MWRC, an average pollutional rating of 90.4 for the Modified National Sanitation Foundations Water Quality Index (WQI) was assigned to the Middle Branch as a result of the 1978 condition survey. The index is based on measurements of nine water quality parameters - nitrate-nitrogen, phosphate, ammonia-nitrogen, turbidity and total solids and a score of over 90 on the 100 point scale indicated excellent water quality. The index, however, is somewhat limited since it does not reflect the presence of toxic materials, aesthetic qualities and other parameters which may be detrimental to the intended water use.

Evaluation of data collected by the NED for the stream sampling stations upstream and downstream from the reservoir echoes the findings of the MWRC: the waters are of high quality and usually meet or exceed technical requirements of their present classification. Dissolved oxygen levels are high, always above 5 mg/l and generally greater than 75 percent of saturation. Analysis of DO data collected from the inflow and outflow stations indicates that percentages of saturation tend to decrease slightly as flow passes through the reservoir and then increase slightly as flow approaches the Westfield River. Flows from the Middle Branch appear to have little effect on the dissolved oxygen concentrations of the main stem of the Westfield River. The majority of the pH measurements in the Middle Branch are within the 6.5 standard unit (SU) to 8.0 SU range, however, approximately 15 percent of the values are less than the minimum 6.5 SU criteria. The low values are apparently the result of the "acid rain" phenomena since there are no known point source discharges upstream from the project.

Water temperatures exceed the 68^{o}F limit for cold water fishery in approximately 25 percent of the observations at the inflow station and in approximately 35 percent of the observations at the outflow station. As can be seen, outflow temperatures have increased over inflow temperatures by as much as 5^{o} to 9^{o}F during the months from June through September. The increase in temperature is caused by the release of warm surface waters, the result of the present operating condition by which all discharge is by gravity flow over a weir located in front of the flood control outlet.

A cold water release study was coordinated between NED and the Commonwealth of Massachusetts Division of Fisheries and Game during the summer of 1979. A small quantity of outflow (5 cfs) was released into the Middle Branch from a blowoff on the water supply line at the toe of the dam. This release was instituted to ascertain if there would be any benefit to cold water fishery downstream from the dam. It was determined during the period of measurement and observation (from May through July) that the only benefit was creation of a cold water refuge in a 250-foot channel below the outflow which quickly disappeared upon mixing with the flood control discharge. From this analysis, it was concluded that a more substantial flow would be required if any improvement to the downstream mile long stretch of cold water fishery is to be expected.

Color levels increase from an average of 17 platinum-cobalt (Pt-Co) units to 25 Pt-Co units as flow passes through the project. The higher color levels tend to occur during the summer and occur mostly in the downstream sampling station. Turbidity levels are low, averaging about 1.5 Jackson Turbidity Units (JTU) and remain essentially unchanged as flow passes through Littleville Lake.

Dissolved metal concentrations are generally low; however, elevated levels of iron, manganese, lead, zinc and mercury have been recorded. Iron and manganese show a slight increase as flow passes through the reservoir, with iron and manganese levels for both stations exceeding the maximum criteria for drinking water standards of 0.3 mg/l and 0.05 mg/l approximately 25 percent and 7 percent of the time, respectively. The concentrations of these two parameters, however, do not exceed the criteria established to protect sensitive aquatic life. Data collected for zinc, lead, and mercury indicate that concentrations may be high enough to be harmful to sensitive aquatic life, however, the data set on these parameters are incomplete.

Levels of the primary nutrient, phosphorus is low in the stream, having concentrations generally less than the respective 0.05 mg/l criteria needed to support algae blooms for streams entering a reservoir. Nitrogen levels are moderate ranging from 0.05 mg/l to 0.65 mg/l, although average levels are slightly less than the 0.3 mg/l criteria needed to support algae blooms for streams entering a reservoir.

Only a minor amount of coliform data was collected such that a complete interpretation could not be made. However, total coliform levels indicate that the class A standards were violated most of the time in the inflow station. The reason for this violation is not known but it appears that it is not of human origin since fecal coliform criteria were not violated.

In other analyses, the waters were found to be "soft" having low alkalinity, which is typical of New England waters.

Lake Water Quality

Plates B-3 through B-8 show the vertical distribution of temperature and dissolved oxygen in Littleville Lake for the period May through November 1970. These profiles do not represent the exact shape of the reservoir because they reflect only the depths and locations of the sampling stations where data were actually collected. As the profiles show, the reservoir stratifies into three distinct layers during the period June through October. The three distinct layers are: the upper layer or epilimnion, where the water is of substantially uniform temperature and density from thermal and wind-related mixing; the lower layer or hypolimnion, where very little mixing goes on; and a middle layer or metalimnion, which separates the epilimnion and hypolimnion and is generally defined as a layer where water temperatures fall off by 0.5°F or more in each vertical foot. The year 1970 was one of the driest years since the completion of the dam in 1965. However, because flows are discharged over a weir and therefore are withdrawn from the epilimnion during both dry and wet years, stratification patterns which developed in 1970 are considered to be typical. This year was chosen for presentation of existing conditions because it is the only one of the study years chosen for thermal simulation analysis (described later in this report) for which profile data exist.

As can be seen in the plates, stratification begins to develop in May and reaches its peak during the period July through October, having a maximum top to bottom temperature differential of 25F° during August. Strong stratification continues in October and is the direct result of the combination of the preceding hot summer weather and low flows. (Average flows over the period of record at Goss Heights, Massachusetts gage during July, August, September and October are 34 cfs, 32 cfs, 40 cfs and 54 cfs, respectively.) Hypolimnion temperatures are shown to change very little throughout the course of the year because of surface water withdrawal at the outlet weir. The only hypolimnion mixing which does occur is the result of the fall and spring overturning; the spring overturning normally being of lesser consequence.

Plate B-8 (14 November) shows typical late fall stratification conditions prior to overturning and depicts the beginning impact of low inflow temperatures on the reservoir. As can be seen on the plate, inflow having low temperatures (and high DO levels) travels along the bottom causing some general mixing in the impoundment. Further surface cooling due to dropping air temperatures and a combination of current and wind completes the mixing and the fall overturning cycle. By January the lake has an ice cover while the bottom of the reservoir maintains a 40°F level (the temperature at which water is the densest). Winter stratification is weak with only an estimated 2F° difference between the top and bottom of the lake. Isothermal conditions return in late March or early April and summer stratification begins again in late April or early May.

Thermally induced density stratification affects dissolved oxygen (DO) levels in Littleville Lake. Dissolved oxygen levels decrease from the upper ends of the reservoir to the lower ends and from the surface of the reservoir to the bottom. Thus, the highest DO levels were at the surface near the point of inflow to the reservoir and the lowest levels were at the bottom near the dam.

Dissolved oxygen levels also change seasonally with the lowest DO levels occurring in the summer and early fall. These changes are not directly correlated with water temperature changes but appear to be related to the biological decay of settled organic matter since the cool deeper waters in the summer have less DO than the warm surface waters. This can be seen plainly during the months of August and October when dissolved oxygen levels dropped as low as 3 mg/l and 2 mg/l, respectively. If there were no biological decay of organic matter during this period, the dissolved oxygen concentration at the related temperatures would be close to the saturation levels of 10.8 and 11.6 mg/l, respectively.

Dissolved oxygen levels may have reduced even further to the point of attaining near anaerobic conditions in the deep portion of the lake (below elevation 450 feet NGVD) near the dam but data in this region of the impoundment were not collected during 1970. Profile data collected in other years indicate that DO levels have dropped to as low as 0.7 mg/l in the deep area near the dam during the same time of year. This problem may not be as significant as one might expect since the volume of the reservoir below elevation 450 feet NGVD is only 150 acre-feet, or less than 2 percent of the water supply pool.

The normal range of DO levels extends from about 15 mg/l near the surface during the winter to near anaerobic conditions in the deeper areas of the pool during the summer.

Limited nutrient data gathered at the Littleville Lake profile stations indicates relatively low levels of phosphorus and inorganic nitrogen. Phosphorus concentrations generally ranged from less than 0.01 mg/l to 0.02 mg/l during late summer and early fall with a high value of 0.1 mg/l at the bottom of the reservoir. Excluding the high value near the bottom, the average concentration during the monitoring period was just under the 0.015 mg/l threshold level needed to maintain an algae bloom. Nitrite-nitrate levels ranged from less than 0.05 mg/l to 0.27 mg/l, with the highest values recorded near the bottom of the reservoir. Average values of nitrite-nitrate were about 0.09 mg/l which is much less than the minimum concentration needed to maintain an algae bloom. Ammonia concentrations were even lower in all stations averaging less than 0.05 mg/l. From these values, and from the fact that influent phosphorus levels are relatively low, it is unlikely for a bloom of any significance to occur at the present time.

Of the metals' concentrations obtained during the monitoring period, iron and manganese were the only ones with any excessive levels. These occurred near the bottom only and reached 1.2 mg/l and 0.61 mg/l, respectively. The apparent reason for the excessive levels is the biological decomposition at the soil-water interface which produces near anaerobic conditions at the bottom of the pool and which, in turn, enhance the solubility of the iron and manganese. This phenomenon can be further substantiated by a review of the pH levels in the reservoir; as anaerobic conditions are approached, pH levels tend to drop off as evidenced by occasional relatively low levels of pH (6.4 SU) at the bottom of the pool.

PREDICTED POST-DEVELOPMENT WATER QUALITY

General

As previously stated, the two alternative hydropower developments evaluated in this study will use the same run-of-river operation mode but will have different penstock arrangements. Alternative 1 would utilize the existing 48-inch diameter water supply line, with its existing multilevel intake structure while alternative 2 would use the existing high level flood control conduit with its present weir overflow intake structure. Plan and profile views of both the existing flood control conduit and the water supply outlet works are shown on plates B-17 and B-18, respectively.

A reservoir temperature simulation model was applied in the analysis of both alternatives, and impacts were determined through comparisons of model output. A generalized version of the WESTEX reservoir heat budget model as developed by the Hydraulics Laboratory of the Waterways Experiment Station was used in the course of this study. The model is enhanced by state-of-the-art techniques in reservoir hydrodynamic modeling thus lending increased validity to the results of this study.

Thermal Simulation

Model Description

WESTEX is a reservoir budget model that simulates the vertical distribution of heat in a reservoir, the resultant vertical profile of temperature and the temperature of the discharge. The model is one-dimensional under the assumptions of discrete, uniformly thick and homogeneous horizontal layers. Accounted for in the thermal budget analysis are heat advection in by inflow, advection out by outflow, surface heat exchange including deep penetration of shortwave solar radiation, and internal dispersion of heat including that caused by wind mixing. A water balance is maintained by the model, and selective withdrawal techniques for weir and orifice flow are used to describe withdrawal zones within the reservoir. Heat transfer at the mud-water interface is assumed negligible.

A period up to 365 days may be simulated with the model; however, the model is most applicable during the stratification period which for southern New England generally runs from April through October. Model output consists of a daily accounting of inflow, outflow, pool elevation and predicted outflow temperature. More detailed output consisting of the predicted temperature profile and withdrawal zone velocity profile is presented for days of special interest specified by the user.

Model Calibration

The ability of the WESTEX model to accurately similate the heat budget of Littleville Lake and predict the resultant temperature structure was checked by calibration against observed temperature profiles measured in June, July, August, October, and November 1970. Calibration is accomplished by fine tuning the values of two input variables, BETA and LAMBDA, that affect the mechanics of heat distribution in the lake. BETA represents the fraction of incident shortwave solar radiation absorbed in the top layer of the reservoir, and LAMBDA is a decay coefficient that controls the rate at which the remaining radiation is is absorbed in lower layers. The two variables acting in concert greatly influence the shape of the temperature profile and influence the overall temperature structure of the reservoir.

All required meteorological, hydrological and operational data for 1970 were available with the exception of a daily record of inflow temperatures. These were constructed through development of a regression equation relating observed instantaneous water temperatures measured at monitoring station LL01 to daily average air temperature and calculated inflow rates. Air temperature data were obtained from Corps of Engineers Knightville Dam, about 2 miles north of the reservoir, while water temperature data collected on an aperiodic basis from July 1970 through October 1981 were used in this analysis. Inflow rates were calculated using a mass balance analysis through the solution of the storage continuity equation. Data for pool elevations were taken from the daily operational log for the project, while data for outflows were taken from the USGS gage just downstream from the dam at Goss Heights, Massachusetts. The resulting regression equation took the form:

$$T_i = 15.35 + 0.5378\ A_i + 0.2122\ A_{i-1} - 0.01248Q_i$$

where:

T_i = Water temperature for a day i, ^oF

A_i = Average air temperature for day i, ^oF

A_{i-1} = Average air temperature for day i-1, ^oF

Q_i = Average discharge for day i, cfs

The multiple correlation coefficient and standard error of estimate of this equation are 0.957 and 2.89^o, respectively. This equation was then used to compute inflow water temperatures by substituting 1970 air temperatures and inflow rates.

Plots of observed and computed (using the WESTEX model) temperature profiles for June, July, August, October and November are shown in plate B-9. These satisfactory results were obtained with values of 0.6 and 0.3 for BETA and LAMBDA, respectively. Observed and computer temperature profiles match reasonably well, and the choice of values for the calibration variables is considered to be valid.

Selection of Study Years

Selection of study years was based on a review of May through October records of mean monthly streamflow for an adjacent watershed (West Branch of the Westfield River at Huntington, Massachusetts; D.A. = 94 sq. mi.) and average air temperatures recorded at the National Weather Service station at Bradley International Airport (located about 25 miles southeast of the project) and at the town of Amherst station in Amherst, Massachusetts (located 24 miles east of the project). The May through October period was selected because experience has shown that thermal stratification will generally occur throughout this period within the Westfield River Basin. Records for both the streamflow gaging station, the National Weather Station, and the town of Amherst station extend back 72 years, 93 years and 57 years, respectively, however it was decided to limit the selection of study years from 1970 to date because of the readily available operational data of the dam. Use of gaged records before this time would require that reservoir routings be completed to simulate the hypothetical existence of the reservoir as it presently is operated. Also, the regression analysis used to obtain inflow temperatures is based on the period 1970 through 1981 and use of the regression analysis for years in this period would provide additional credence to the results. Even though the absolute extremes of runoff and temperature may not have been obtained, a sufficiently wide range of data was used to develop a good estimate of extreme conditions.

Four years with differing hydrometeorological conditions were chosen to enable the study to envelope operating conditions which may develop for each power development alternative. Combinations of above normal and below normal hydrologic and meteorologic conditions were considered in the selection of these study years. The four years discussed below were selected for this study.

Year	Hydrometeorological Conditions
1970	General Classification - Hot, dry year. Near normal temperatures in June, July and September; above normal temperature in May, August, and October. Near normal runoff in May; below normal runoff from June through October.

Year	Hydrometeorological Conditions (cont.)
1972	General Classification - Cool, wet year. Near normal temperature in May, July and September; below normal temperature in June, August, and October. Above normal runoff in May, June and July; normal runoff in August; below normal runoff in September and October.
1975	General Classification - Hot, wet year. Near normal temperature in June and August; below normal in September; above normal temperature in May, July and October. Below normal runoff in May; above normal runoff in June through October.
1980	General Classification - Cool dry year. Near normal temperature in May, August and September; below normal temperature in June, July and October. Below normal runoff in May through October.

Simulation of Alternatives

The two alternatives were modeled for each study year using operational, hydrologic and meteorologic conditions experienced in those years. As described previously, inflows were calculated using a mass balance analysis through the solution of the storage continuity equation. Meteorological data were obtained from the National Weather Service station at Bradley International Airport. Since a continuous record of water temperature data does not exist for the Middle Branch of the Westfield River at its inflow point to Littleville Lake, the water temperature regression equation used in the 1970 calibration study was also used to calculate inflow temperature data for the years 1972, 1975, and 1980.

In the evaluation of alternate 1 in which the water supply conduit was used, the following operations scenario was used in the application of the model:

(a) An assumption was made that the lower port (invert elevation 447 NGVD) would remain open at all times, allowing for flow to occur even during times of powerhouse shutdown. Maximum flow would be equal to 80 cfs.

(b) The next higher level port (invert elevation - 465 NGVD) would be open when release rates exceed the 80 cfs capacity of the lower port. Maximum flow through this port would be 80 cfs.

(c) Discharge rates exceeding the 160 cfs capacity of lower ports would flow over the control weir in the high level flood control conduit (weir crest elevation - 518 feet NGVD). The two upper level ports, invert elevation 483.8 NGVD and 502.2 NGVD, would remain closed at all times.

A maximum flow rate of 80 cfs through the 3-foot diameter circular port produces velocities of approximately 11 fps which is higher than recommended normal port velocities needed for fine control of water quality conditions within reservoirs (reference EM 1110-2-1602). It is believed that these maximum velocities will not be a problem since they only occur during the early part of the stratification period when fine control is unnecessary.

In the evaluation of alternative 2, in which the high level flood control conduit was used, it was assumed that all flows would be discharged over the existing weir into the flood control conduit. This alternative is also representative of the present operation mode at Littleville Lake.

Results

General. Results of the modeling study on Littleville Lake are presented graphically on plates B-10 through B-16. Simulated monthly temperature profiles portraying the effects of the alternative developments in study year 1970 are shown on plate B-10 and a group portrayal of the four study years over the stratification period are shown on plates B-11 and B-12. These plots represent the seasonal development and breakup of temperature stratification at the deepest part of the lake immediately upstream from the dam.. Plates B-13 through B-16 present the simulated outflow temperature of Littleville Lake for both alternatives in each study year.

Effects on Reservoir. As might be expected, major differences between the two alternatives exist; they can be observed in plates B-10 through B-12. Withdrawal from the bottom ports under alternative 1 not only drastically reduces the stratification patterns that would normally develop in the high level release alternative, but temperatures throughout the reservoir are shown to increase significantly. These differences are most pronounced during August and October. Simulated hypolimnion and metalimnion temperatures of alternative 1 are greater by as much as 15F° to 20F° at a given depth. Temperatures in the epilimnion in August are also shown to increase slightly (as much as 2F°) as a result of very little surface water being discharged via the weir. The spread between the comparable epilimnion temperatures increases after August such that by 15 October, there is a 10F° difference. The higher epilimnion temperatures of alternative 1 also extend deeper than those of alternative 2. This overall warming of the reservoir by alternative 1 would mean that wintertime isothermal conditions will occur as much as 2 to 4 weeks later than in alternative 2 based on estimates using the hydraulic residence time of the reservoir as an indicator.

A distinct stratification pattern such as in alternative 2, does not exist in alternative 1; the rate of temperature change from the top to the bottom of the lake is almost constant. The reason for the great difference in profiles is the fact that Littleville Lake has a relatively small volume and even minor amounts of flow drawn from the bottom produces significant effect on the vertical temperature distribution.

Among other readily apparent differences in the profiles is the fact that alternative 2 produces very little mixing in the hypolimnion during each stratification season. By comparison, alternative 1 produces more significant hypolimnetic mixing, which contributes to the weaker stratification pattern in the lake. As can be seen, the hypolimnion temperatures for this alternative are more susceptible to variations in runoff and meteorological conditions, varying by as much as 15F° between study years.

It is believed that the general warming of the lake by alternative 1 may have little effect on the existing cold water fishery within the reservoir, since the depth (and thus the associated volume) of the 68°F isotherm (maximum temperature criteria for maintaining a cold water fishery) has not changed significantly. The maximum change in the elevation of the 68°F isotherm was about 14 feet for all study years in the most critical month, August. Making a conservative assumption that the 14-foot change in elevation of the 68°F isotherm was constant throughout the reservoir, the reduction in cold water fishery volume would be about 2,500 acre-feet (about 40 percent of the volume available for cold water fishery) for alternative 2 at that time of year. The effects of this reduction in cold water volume are expected to be offset by the increase in volume of well oxygenated waters in the hypolimnion due to increased internal mixing induced by the bottom withdrawal operation.

Considering the hydraulic residence time, the shape of the reservoir, and the present dissolved oxygen configuration, it is estimated that the lowest DO levels which could be reached would be 4 mg/l during operation under alternative 1. This level would occur near the reservoir bottom and thus would eliminate concern for increased hydrogen sulfide, iron or manganese levels in the downstream waters.

Effects on Outflow Temperatures. The difference between alternatives is clearly shown in the simulated release temperature plots presented on plates B-13 through B-16. Temperatures easily vary by as much as 20 Fahrenheit degrees between alternatives and sometimes as much as 30F°. Differences in predicted outflow temperatures between alternative plans of development are greatest during the dry years of 1970 and 1980. Generally lesser temperature differences are indicated for 1972 and 1975 because heavy runoff events occurred, which result in more extensive mixing of the lake in alternative 2 and result in the displacement of warm surface waters by weir overflow in alternative 1. The occurrence of surface water outflows can easily be singled out for the years 1972 and 1975 in plates B-14 and B-15; they correspond to the high peaks which occur in May through July in 1972 and throughout the year in 1975.

Operation under alternative 2 would essentially be the same as currently occurs at Littleville Lake and would continue to cause the majority of discharges from 1 June to the end of September to be at temperatures greater than the 68° Fahrenheit maximum criterion for Massachusetts cold water fisheries. Of the 122 days available during this summer period, the number of days at which predicted temperatures exceeded 68° Fahrenheit varied from 76 days in 1972 to 101 days in 1980.

Predicted outflow temperatures under alternative 1 rarely exceed the 68° Fahrenheit criterion. Release temperatures are so low in comparison to the criterion that higher level gates in the multilevel intake may be required on occasion to raise the outflow temperatures or to raise any low dissolved oxygen levels that occur. Further study would be needed to develop optimum operational procedures if this alternative is chosen; however, a simplified assumption can be made that flow would be divided equally between the top (invert elevation 502.2 NGVD) and bottom (invert elevation 447 NGVD) ports during the stratification season. This would increase the temperature of outflows for downstream fish habitat but still allow for internal mixing of the reservoir. A single analysis was completed for study year 1980 to show the effect that this selective withdrawal scheme would have on release temperatures. (The year 1980 was chosen; there would be very little flow over the weir and outflow temperatures would be colder than in other study years). The release temperatures computed for this analysis are labeled alternative 1A on plate B-16. As can be seen, release temperatures fall between those of alternative 1 and alternative 2. Selection of this alternative would require that manual or automatic temperature and DO monitoring of the lake and discharge be performed and that port openings be adjusted so as to optimize water quality conditions for the project.

Future Water Quality Conditions

General

It is expected that future water quality conditions with alternative 2 would vary only slightly from the existing prehydropower condition. The only change in operating conditions from those of the present is the block loading of flow, such as a 12-hour on, 12-hour off type of operation. The average daily flow rate is the same and there would be little significance to in-lake or in-stream water quality.

A major change in water quality conditions would occur if alternative 1 was put into operation. Most of the change would be beneficial since the portion of the Middle Branch from the dam downstream to the Westfield River would meet the temperature criterion for a cold water fishery and also the existing relatively stagnant hypolimnion, which would continue to exist under alternative 2 would be eliminated.

Water quality impacts of both alternatives, which can be characterized as either short or long term, are described in greater detail below.

Short Term Effects

Factors influencing initial stream and reservoir water quality include construction activities and the immediate physical/chemical/biological processes that take place after hydropower operation has been initiated.

In both alternatives, during construction of the powerhouse downstream from Littleville Dam, it is anticipated that there would be a temporary increase of suspended solids and dissolved solids in the Middle Branch of Westfield River and in the Westfield River. These higher levels would clear up as soon as construction is completed.

In alternative 2, initial operation should cause very few short term effects since basically the operations scheme is a continuation of the present operation.

In alternative 1, initial operation should not cause problems if proper operational techniques are used. During times of high spring flow, the bottom portion of the existing lake can be flushed out by using the two lower ports or a combination of the bottom port and an upper port, with any excess flow going over the weir. Color, iron, manganese, total solids and dissolved solids levels would be increased initially but would taper off almost immediately as the stagnant lower portion of the reservoir is flushed out. Dissolved oxygen levels are quite high in the spring, above 8 mg/l and thus there would be no dissolved oxygen or H_2S problems. As dissolved oxygen levels decrease during the remainder of the year, it may be necessary to mix flow from the upper ports with flow from the lower ports on occasion. If it is necessary to use the upper level ports during times of low flow, the release temperatures of the outflow can be adjusted gradually such that there is no more than a few Fahrenheit degrees change in a short time. However, it is only anticipated that this condition would exist for a short while as the biological decomposition of the bottom sediments stabilizes after a few years of flushing with well-oxygenated waters.

Long Term Effects

Of the two, alternative 1 would have the greatest effect on the reservoir and the downstream water quality, principally due to bottom withdrawal of flow. The major effect for this alternative would be that temperature levels of the entire reservoir would increase and downstream temperatures would decrease producing thermal conditions suitable for a cold water fishery. Alternative 2 would essentially maintain the present characteristics of the reservoir with the exception of a block type of hydropower operation in which flow would be released intermittently rather than uniformly throughout the day.

Both alternatives would be subject to a slight amount of increased turbidity in the reservoir as a result of bank instability caused by daily pool fluctuations. This is not expected to be a major problem, however, since the pool will be maintained very close to the level at which it has been maintained since 1965 (518 feet NGVD). Fluctuations between 518 feet NGVD and 525 feet NGVD normally occur on a regular basis because of storm and snowmelt runoff.

Hydropower operation, as it is proposed for alternative 2, should have only minimal effects on the dissolved oxygen levels within Littleville Lake and downstream in the Middle Branch of the Westfield River. The lake will continue to overturn in the spring and fall, reaerating somewhat the stagnant bottom portion in the process. During late summer, dissolved oxygen levels at the lower depths near the dam will approach anaerobic conditions as it now does. It is expected that over the long term, as the reservoir becomes more nutrient rich from settlement of organic matter in the pool, oxygen levels would gradually decrease, creating a more extensive anaerobic condition than exists now. This process is similar to what occurs in natural lakes, which essentially have surface discharge outlets.

In contrast, alternative 1 would provide improvements in the dissolved oxygen levels within the reservoir with slight decreases occurring during the early fall in dissolved oxygen levels downstream from the reservoir. During the spring of the year, dissolved oxygen levels are high and discharge could be made through the lower ports only, or through a combination of bottom and upper ports. As summer progresses, and flows reduce substantially, decomposition of sediment would cause oxygen in the lower layers to be lowered. It is expected that in late summer or early fall, dissolved oxygen levels in the discharge could reach 4 mg/l from biological and chemical processes at the bottom of the pool. Over the long term, it is not expected that oxygen depletion will be as severe as presently exists since a continuous flushing action will take place throughout the course of the year. This flushing will remove many of the dissolved nutrients which are in solution and thus will remove many of the oxygen demanding materials. Based on an average monthly flow of 32 cfs (equivalent to that which exists in the month of August), it is estimated that the entire volume below elevation 455 NGVD (230 acre-feet) could be changed within four days if the bottom port alone is used. This flushing would more than make up for the increased biological activity and increased oxygen depletion which would take place due to the 10°F to 15°F increase in hypolimnion temperature. Winter oxygen depletion at lower levels for alternative 1 are not expected to change since there would be very little change in hypolimnion volume and temperatures would not vary from their present stabilized conditions of approximately 40° Fahrenheit.

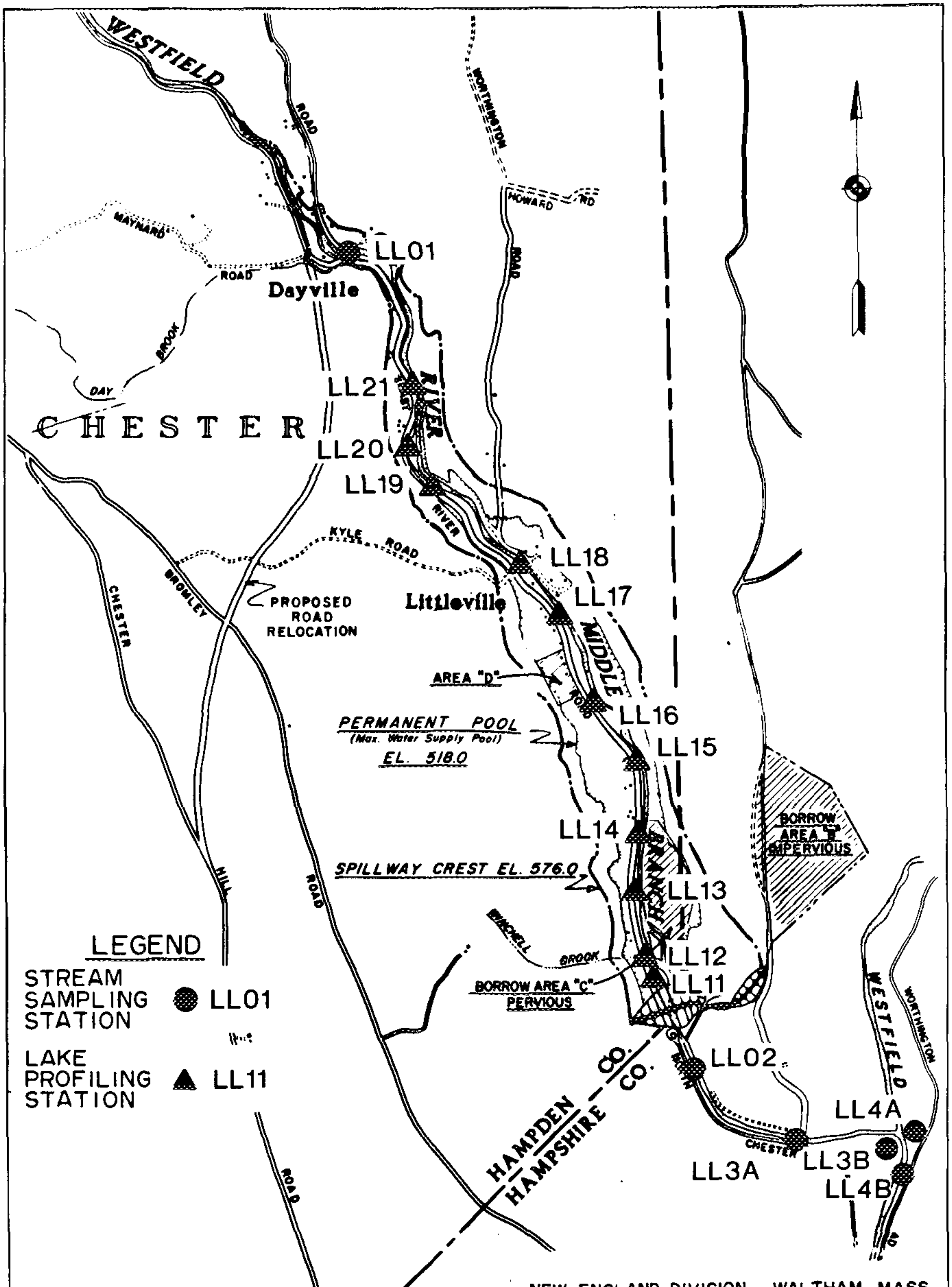
Dissolved oxygen levels in the releases from the low level port of the multilevel outflow structure of alternative 1 should be consistent with what occurs now except during late summer and early fall when dissolved oxygen levels are expected to decrease slightly. Flow with low dissolved oxygen levels (about 4 mg/l) may be discharged from the dam, but it is expected that these levels will increase from reaeration in the tailrace of the powerhouse.

Color, iron, manganese, hydrogen sulfide and ammonia levels are expected to decrease in the hypolimnion as a result of flushing action under alternative 1 while concentrations of these same parameters are not expected to change under alternative 2. The release of these parameters in the operation of alternative 1 should not pose any major problem to any of the downstream used of water since their levels in the lake are expected to substantially decrease from those measured at the present time.

CONCLUSIONS

Results of the thermal simulation and water quality evaluation of the alternative hydropower schemes indicate that although alternative 2 provides for little change from the existing water quality regime, alternative 1 provides not only an anticipated improvement to the low dissolved oxygen content of the reservoir but also provides release temperature reduction such that Massachusetts cold water fisheries temperature criteria are met in the mile long portion of the Middle Branch of the Westfield River below the dam.

The results shown in this report for alternative 1 are based on the plan to use the two lower ports of the existing multilevel structure. The higher ports are also available for use in hydropower operation such that optimal water quality conditions could exist in the reservoir and the portion of the Middle Branch below the dam. A future study on the regulation procedure would be needed prior to implementation of alternative 1.

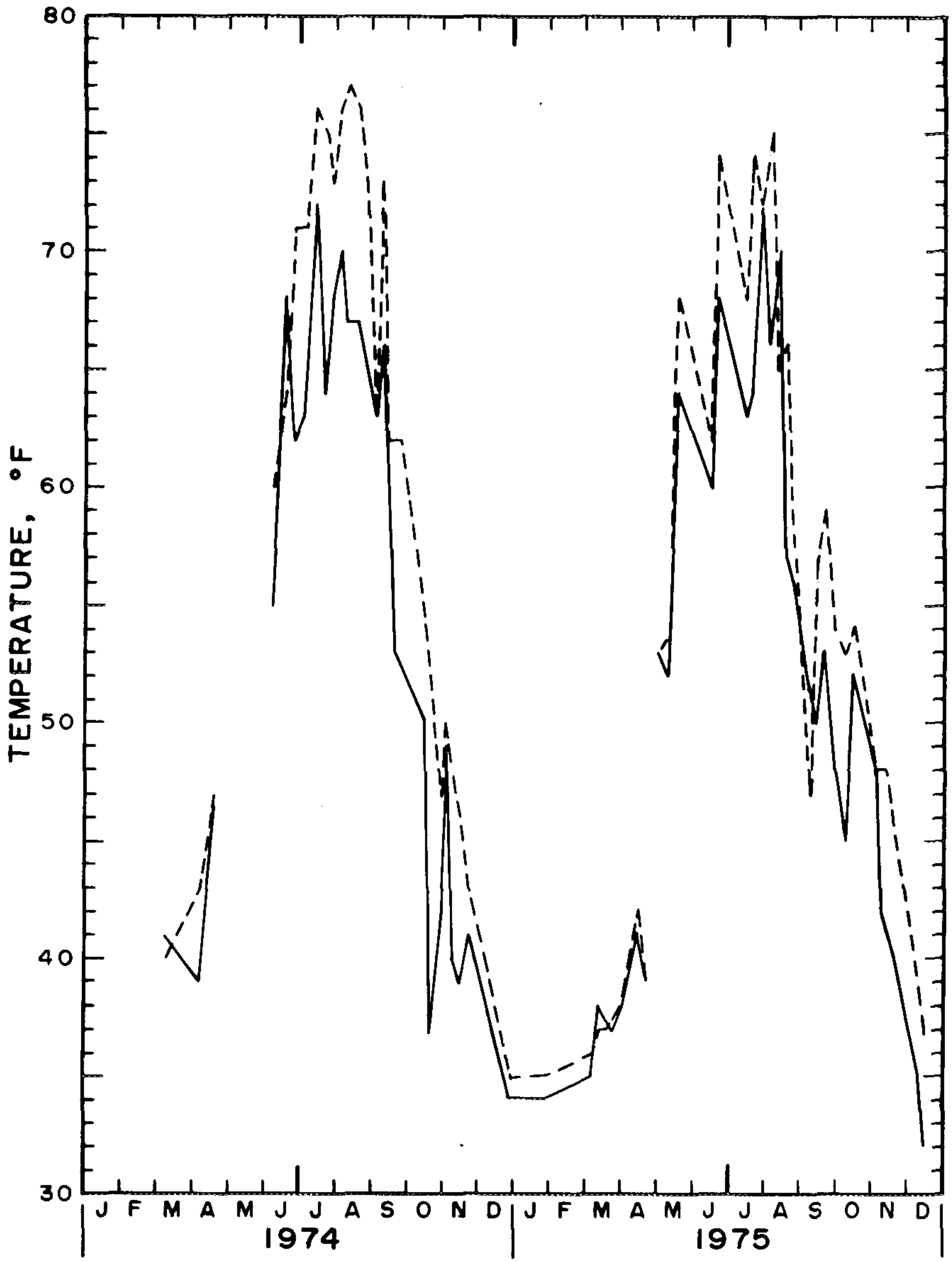


NEW ENGLAND DIVISION WALTHAM, MASS.

LITTLEVILLE LAKE
HYDROPOWER STUDY

WATER QUALITY
SAMPLING STATIONS

MID. BR. WESTFIELD R. MASS.



LEGEND

UPSTREAM TEMPERATURES ———

DOWNSTREAM TEMPERATURES - - - - -

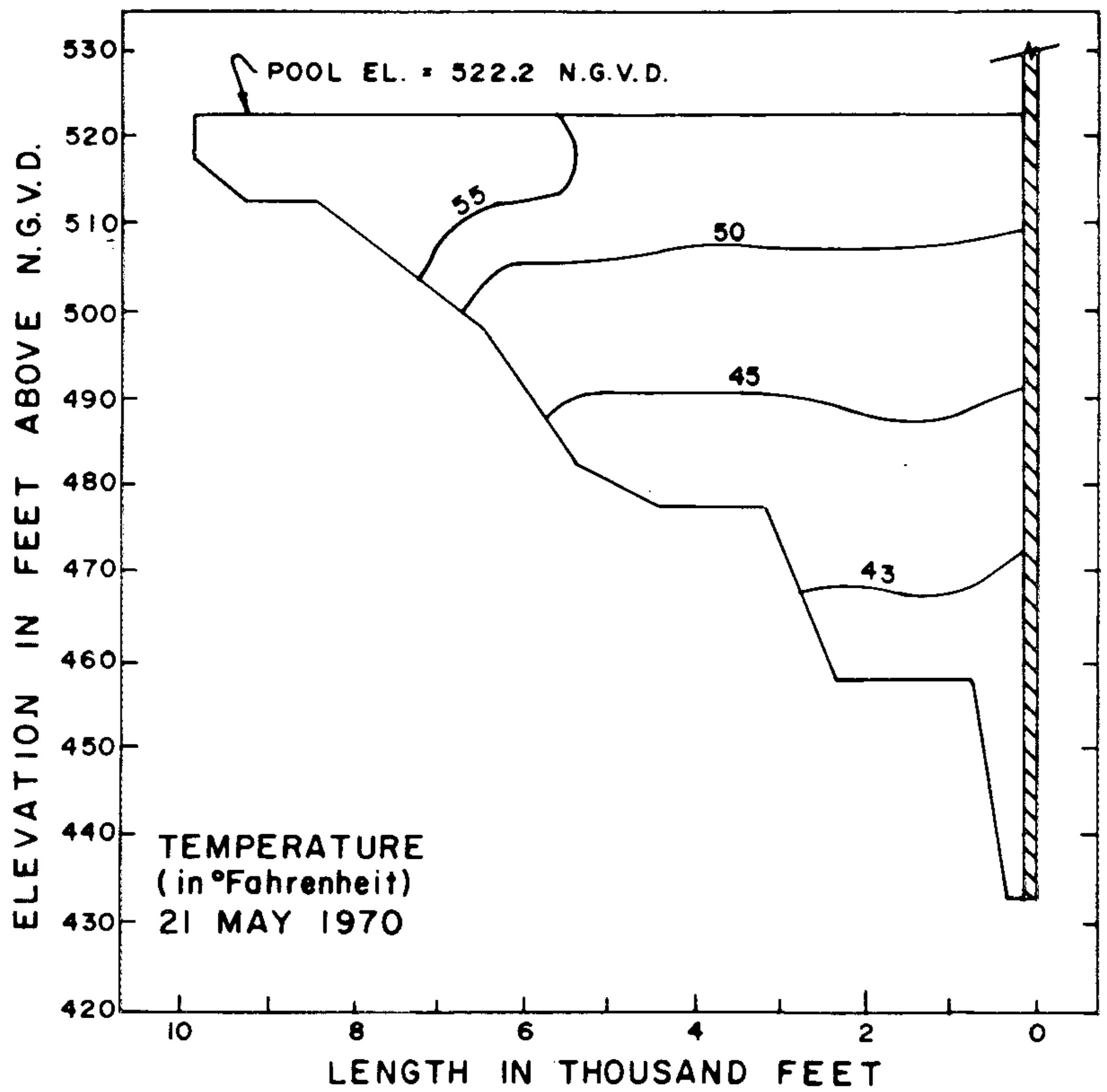
NEW ENGLAND DIVISION, WALTHAM, MASS.

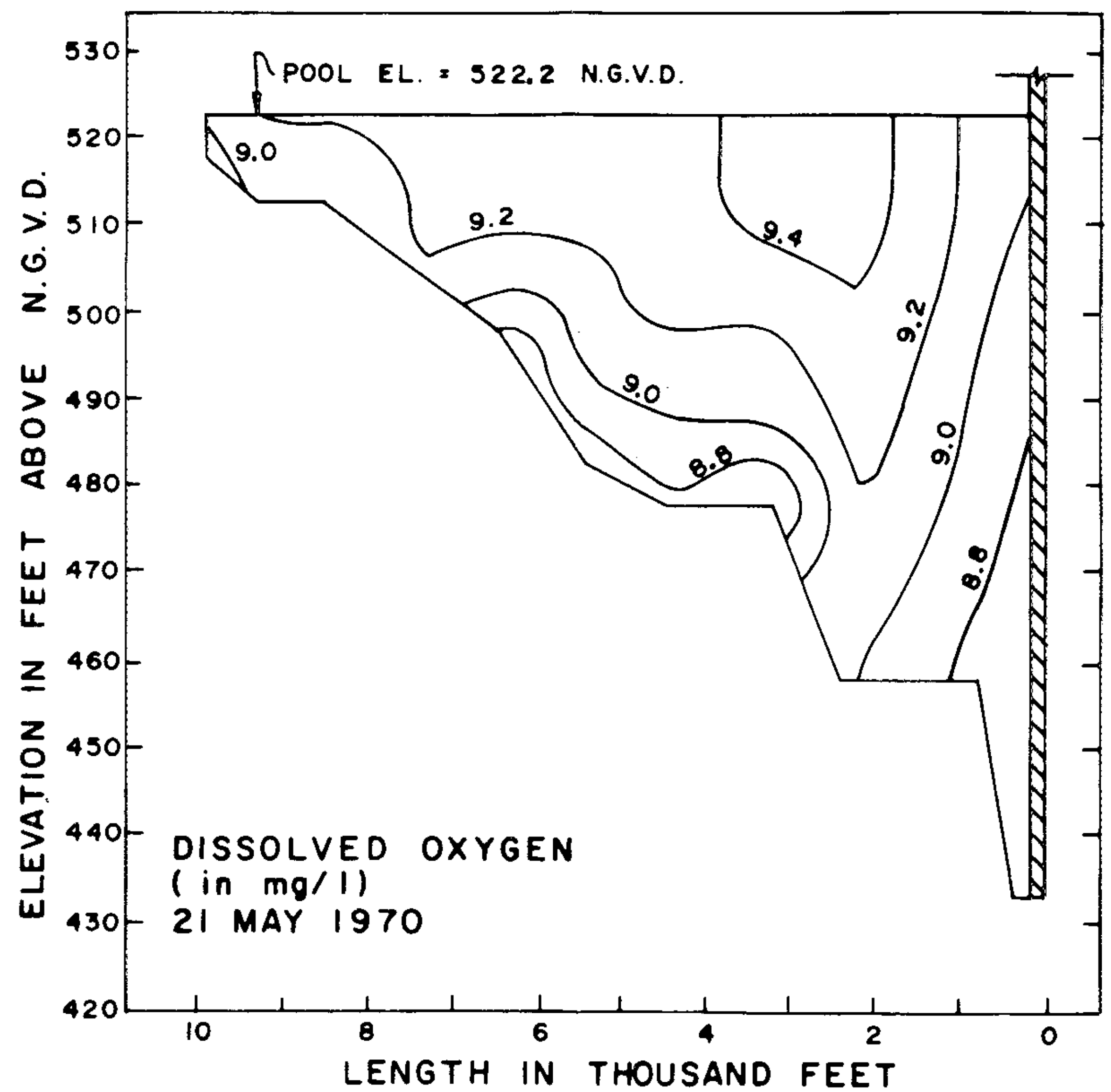
LITTLEVILLE LAKE
HYDROPOWER STUDY

STREAM TEMPERATURE

MIDDLE BRANCH WESTFIELD R. MASS.

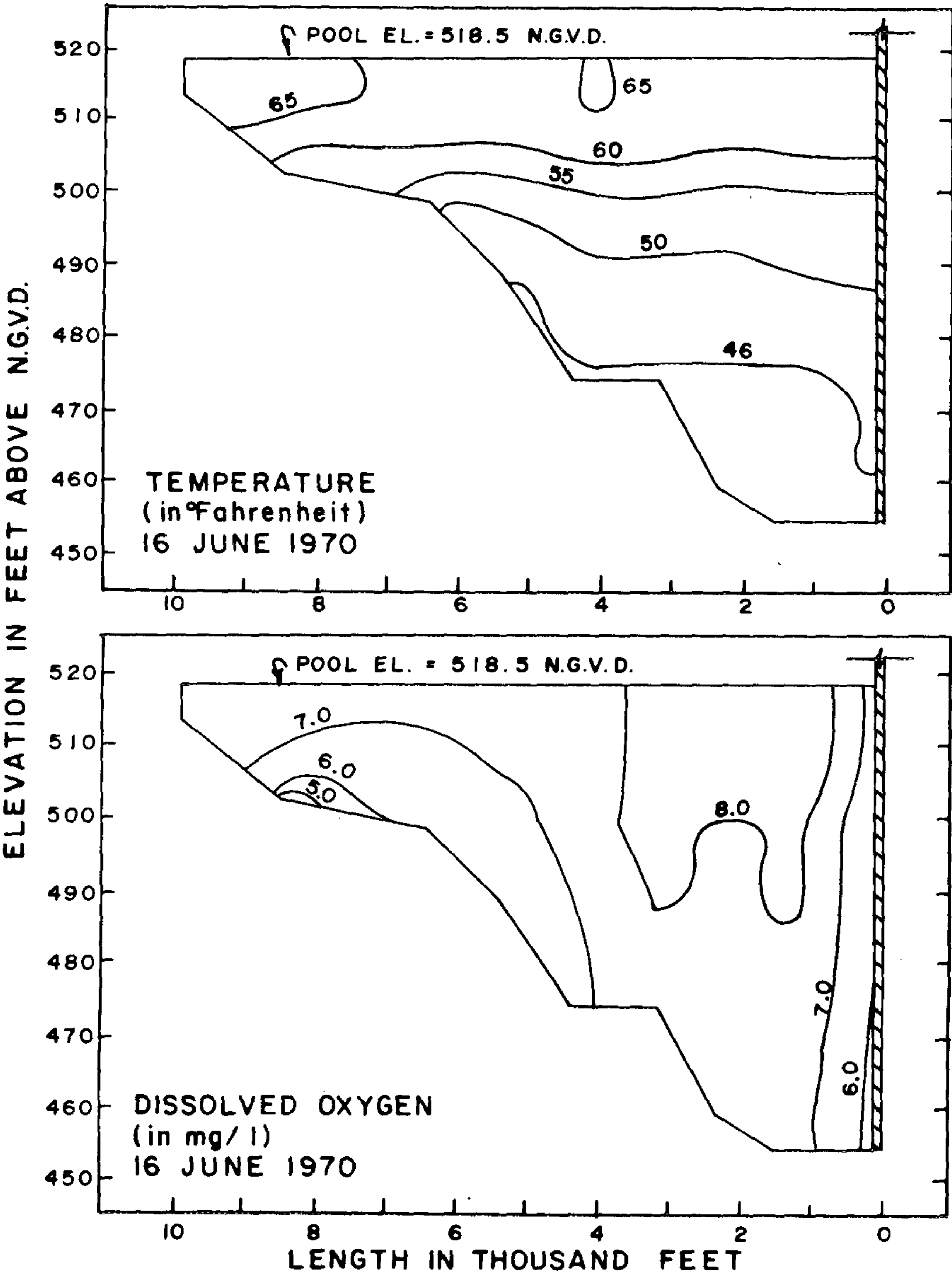
PLATE B-2





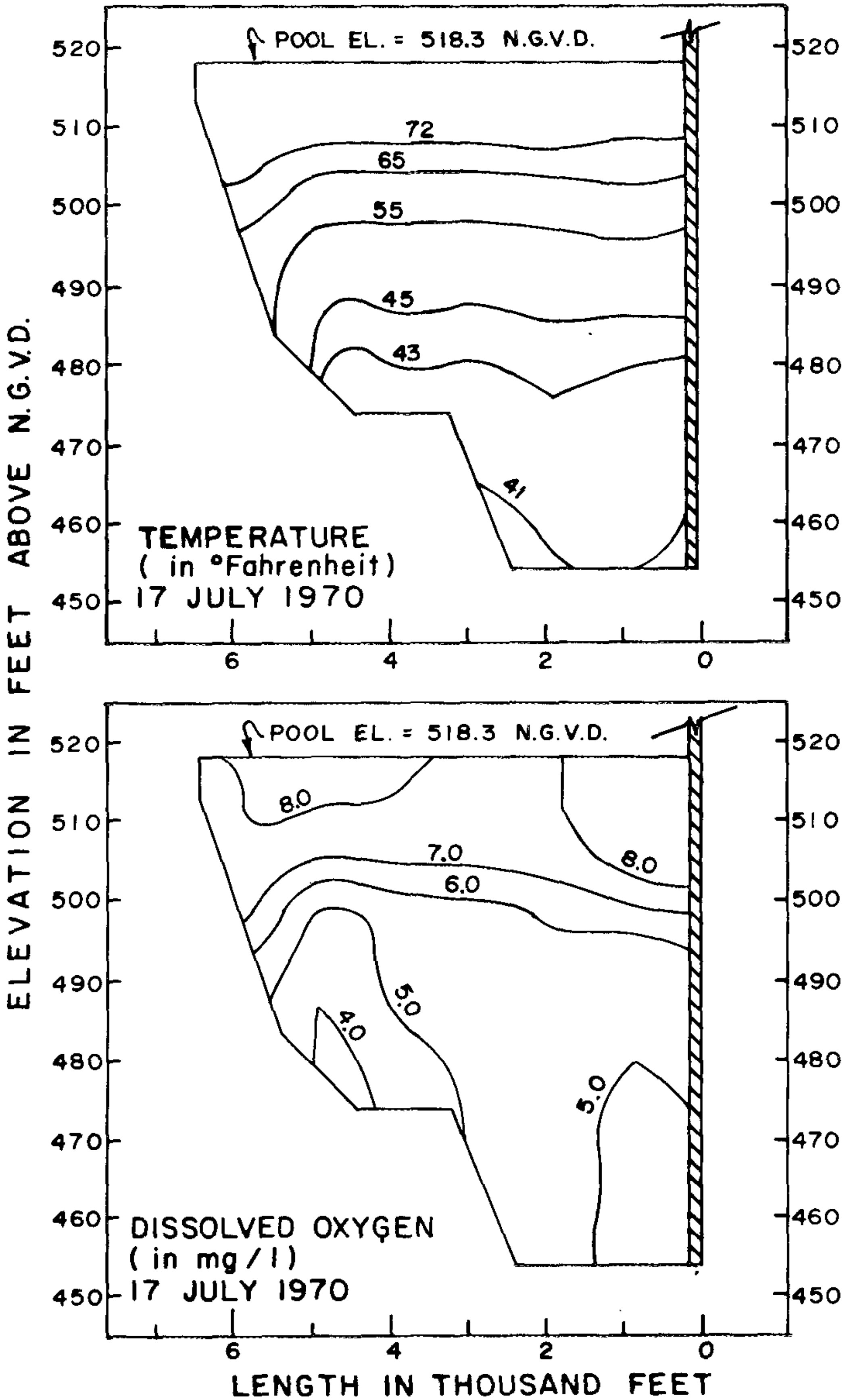
LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND
DISSOLVED OXYGEN REGIME
MAY 1970
MID. BR. WESTFIELD R. MASS.

PLATE B-3



LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND
DISSOLVED OXYGEN REGIME
JUNE 1970
MID. BR. WESTFIELD R. MASS.

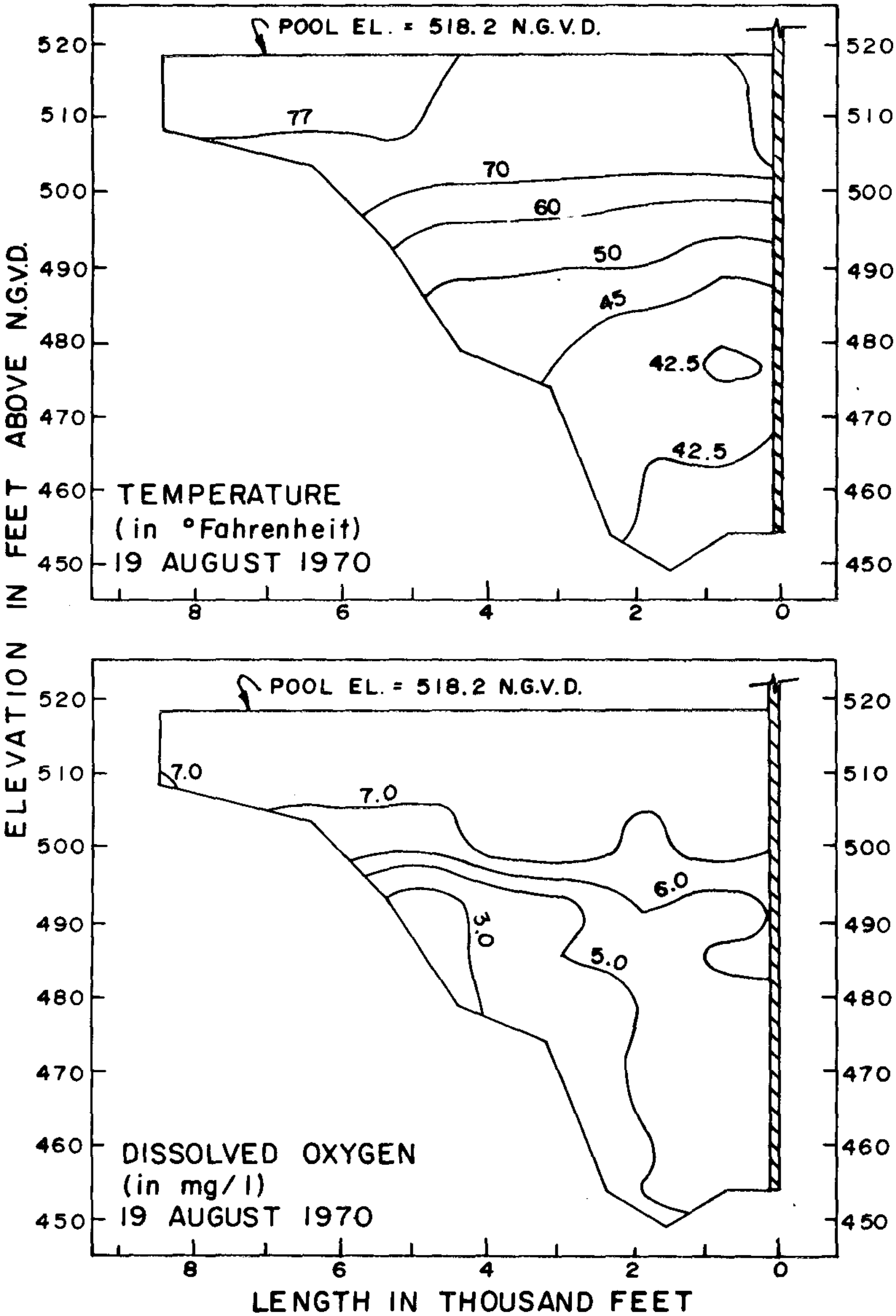
PLATE B-4



LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND
DISSOLVED OXYGEN REGIME
JULY 1970

MID. BR. WESTFIELD R. MASS.

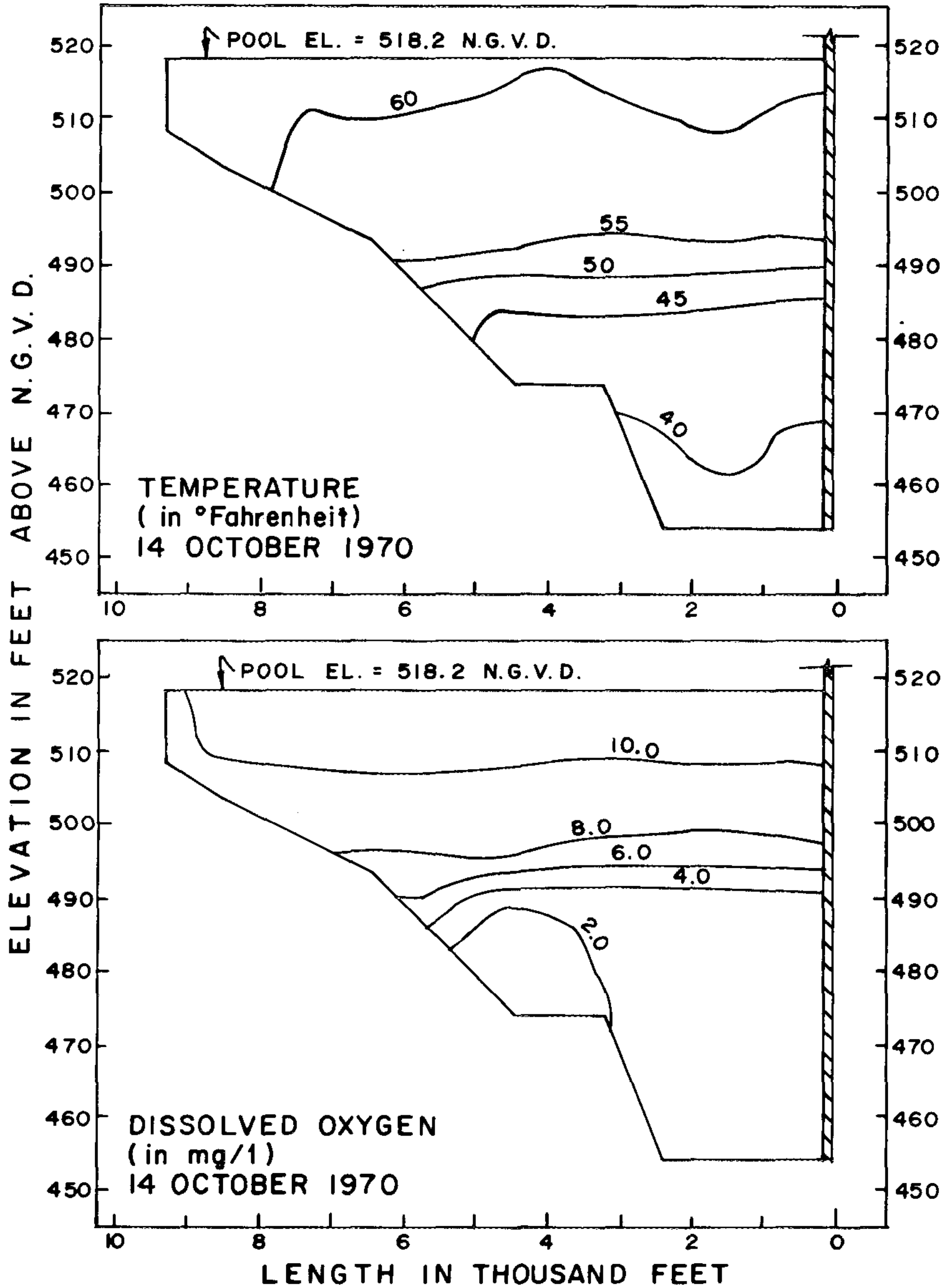
PLATE B-5



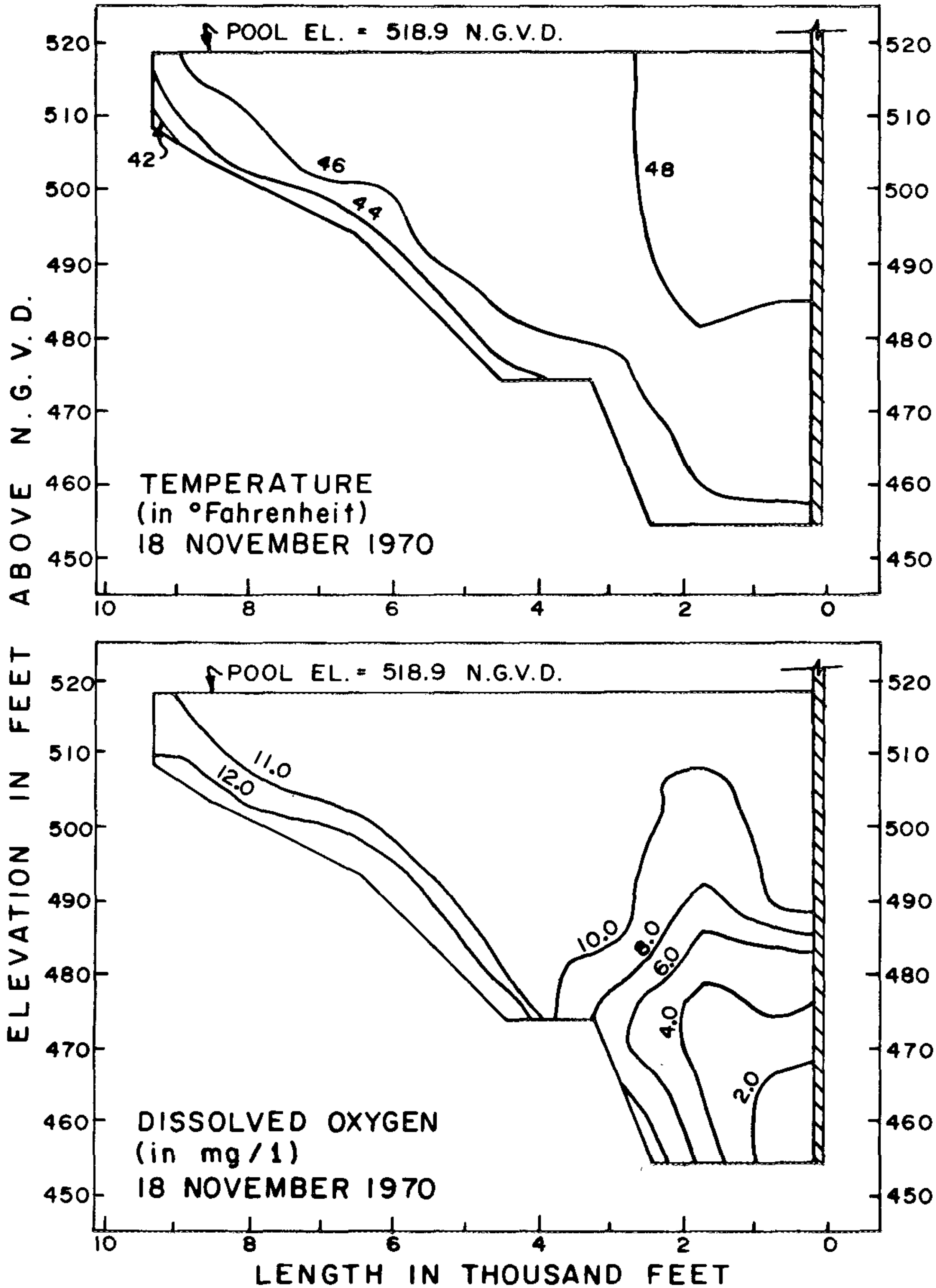
LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND DISSOLVED OXYGEN REGIME
AUGUST 1970

MID. BR. WESTFIELD R. MASS.

PLATE B-

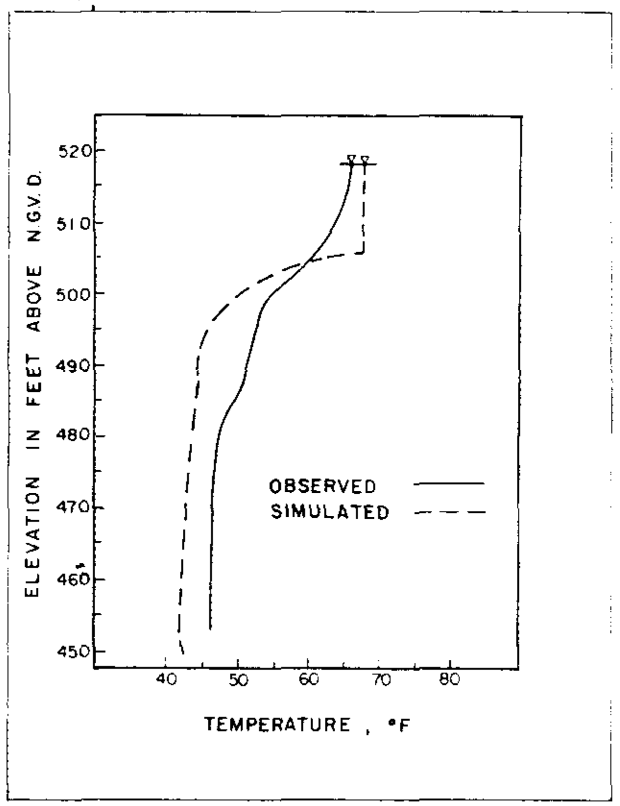


LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND DISSOLVED OXYGEN REGIME
OCTOBER 1970
MID. BR. WESTFIELD R. MASS.

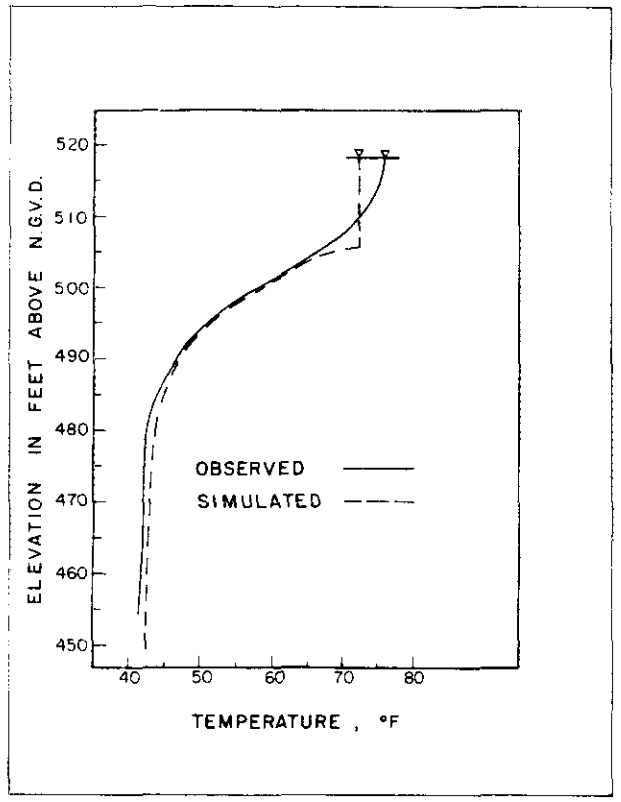


LITTLEVILLE LAKE
HYDROPOWER STUDY
OBSERVED TEMPERATURE AND DISSOLVED OXYGEN REGIME
NOVEMBER 1970
MID. BR. WESTFIELD R. MASS.

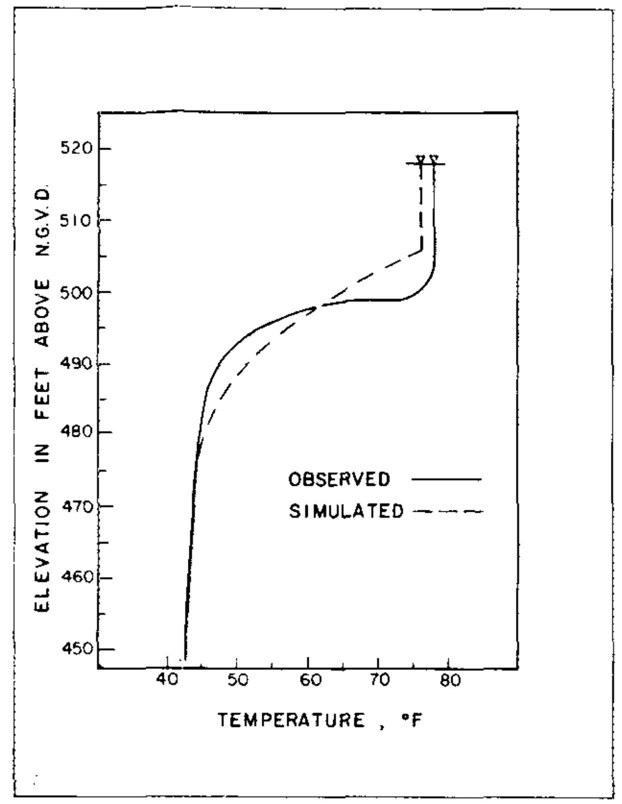
PLATE B-8



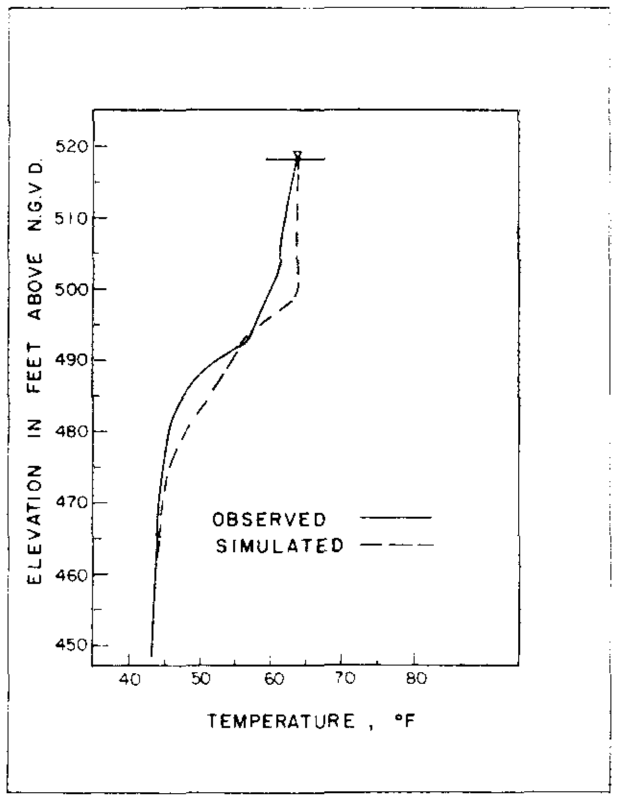
16 JUNE 1970



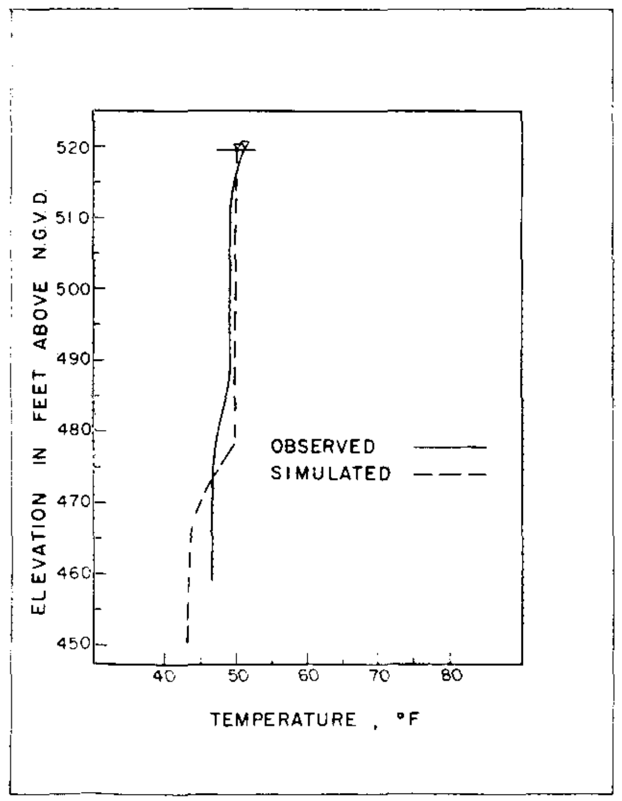
15 JULY 1970



18 AUGUST 1970



14 OCTOBER 1970



17 NOVEMBER 1970

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

LITTLEVILLE LAKE

HYDROPOWER STUDY

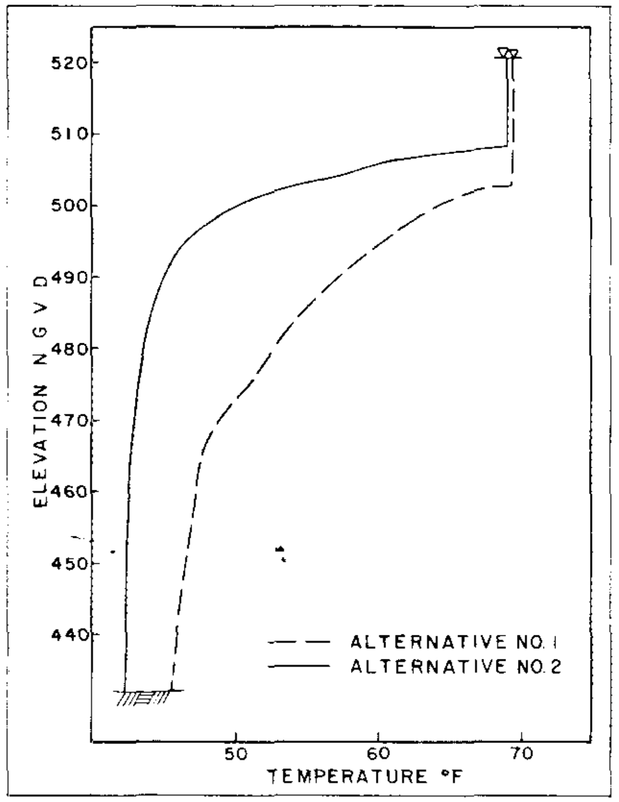
OBSERVED AND SIMULATED

TEMPERATURE PROFILES

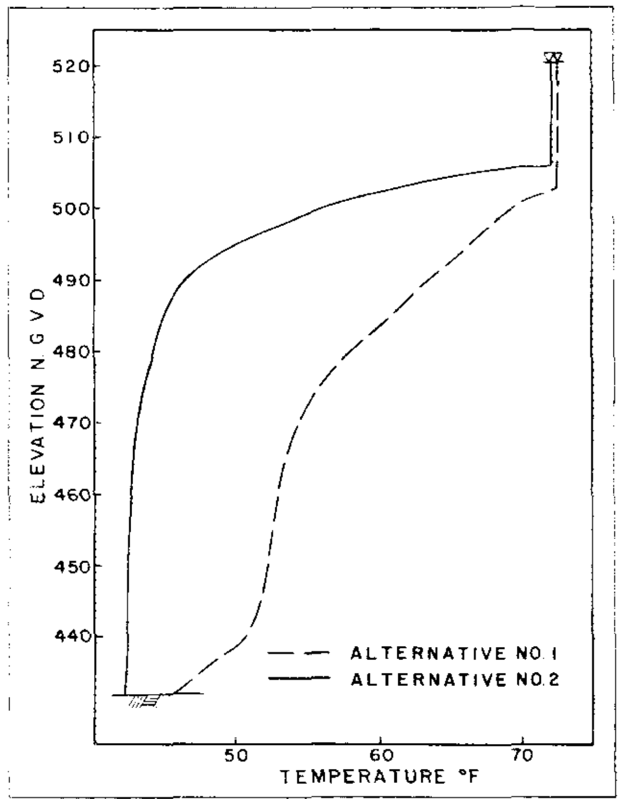
1970

MIDDLE BRANCH WESTFIELD RIVER MASS

PLATE B-9



15 JUNE 1970



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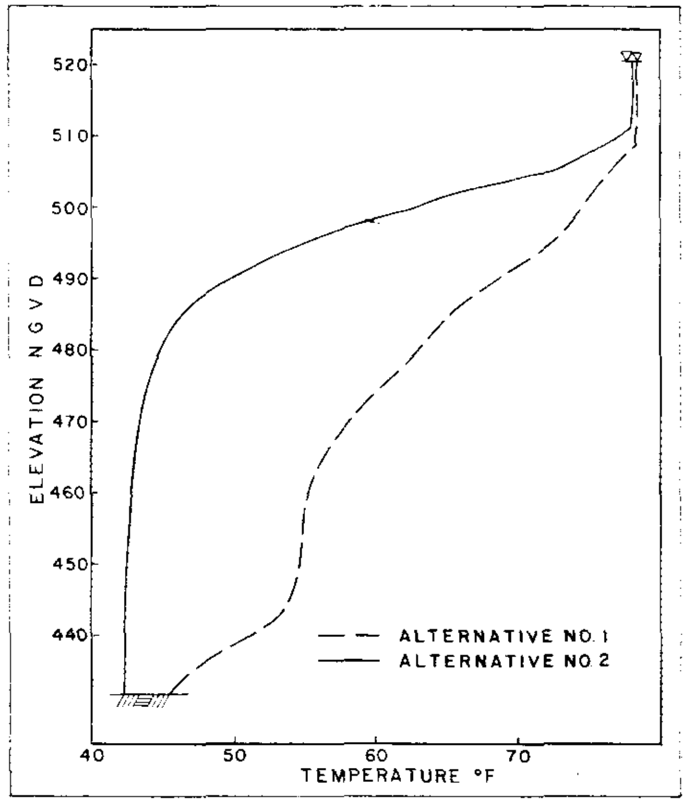

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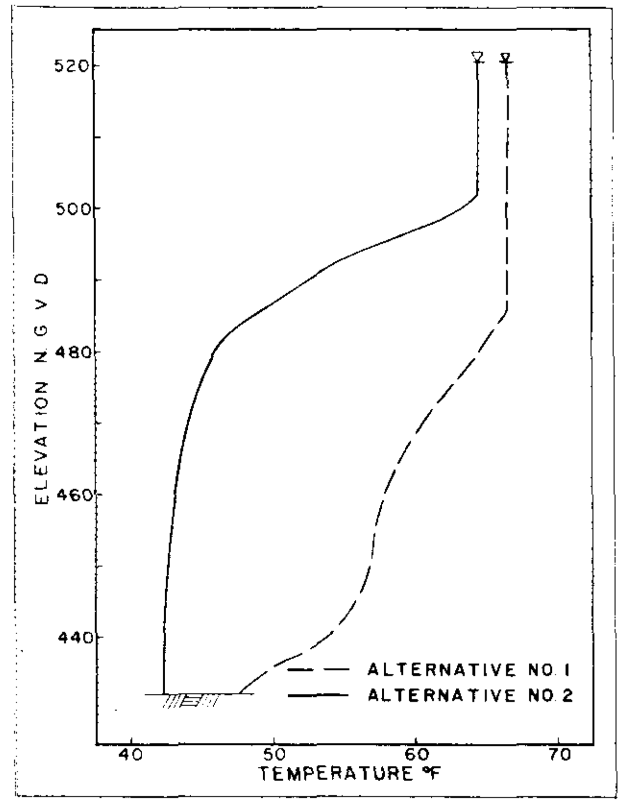
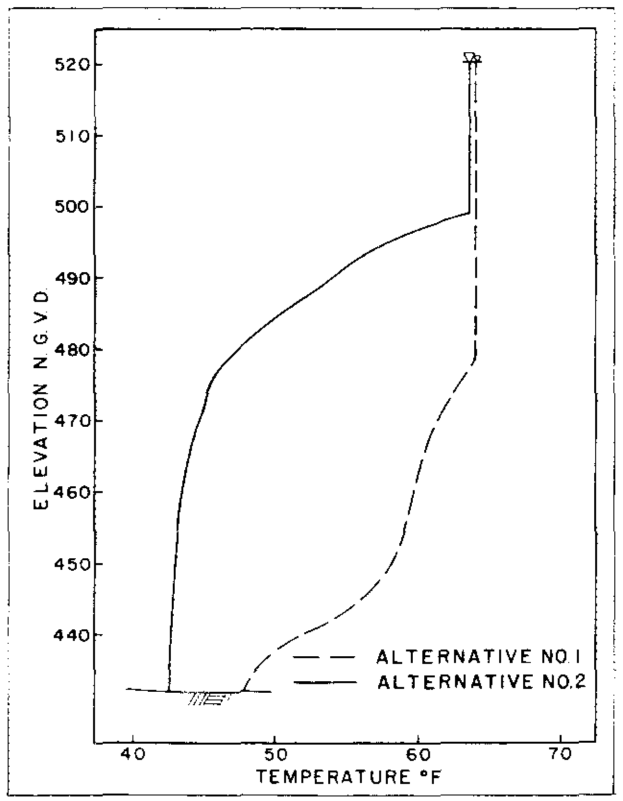


15 SEPTEMBER 1970



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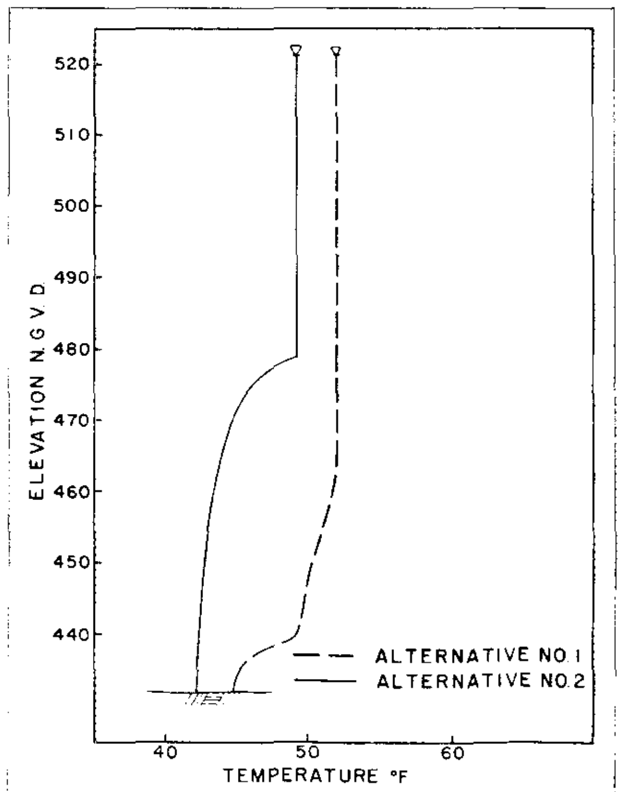

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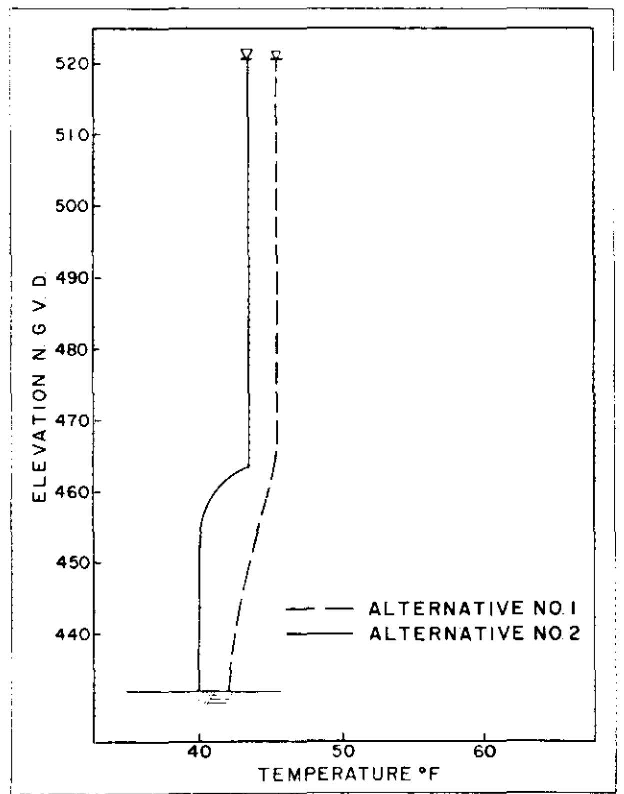

30 NOVEMBER 1970

DEPARTMENT OF THE ARMY
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WALTHAM, MASS.

LITTLEVILLE LAKE

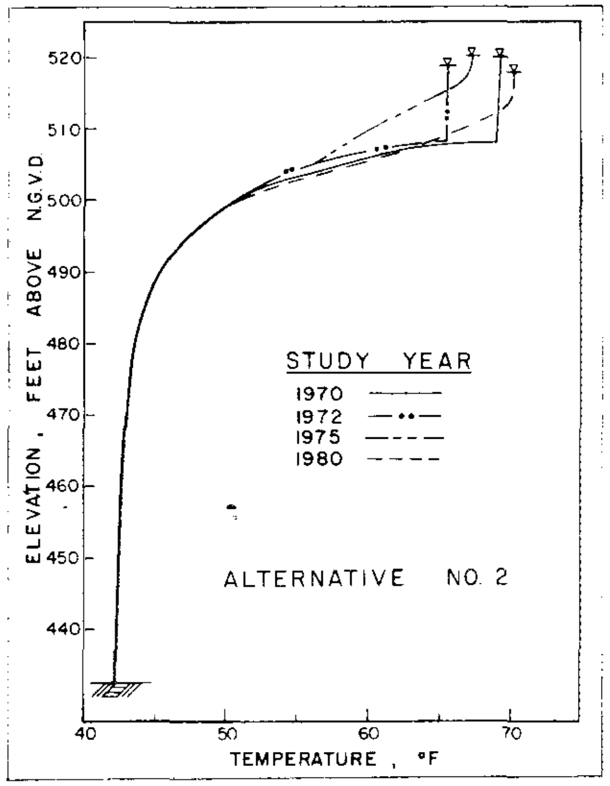
HYDROPOWER STUDY

SIMULATED TEMPERATURE PROFILES

STUDY YEAR 1970

MIDDLE BRANCH, WESTFIELD RIVER MASS

PLATE B-10



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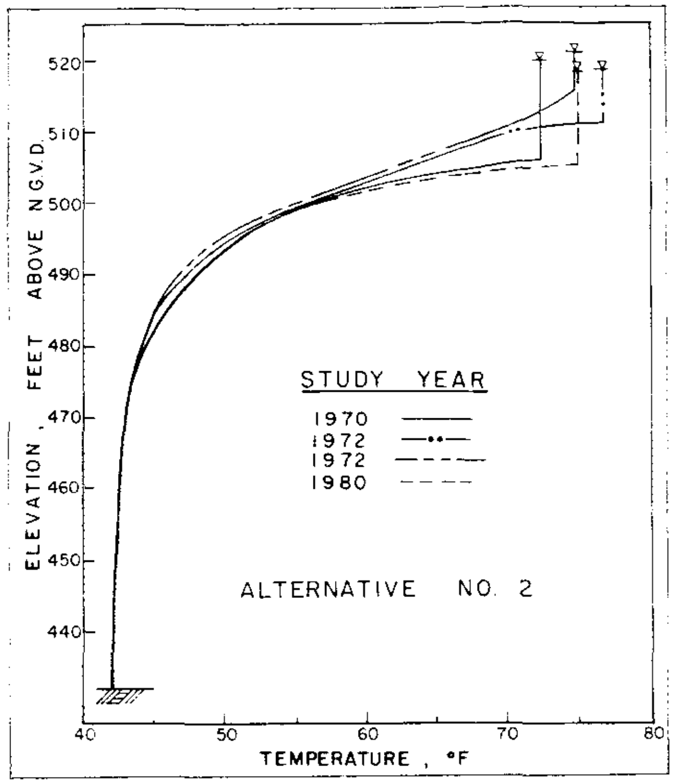

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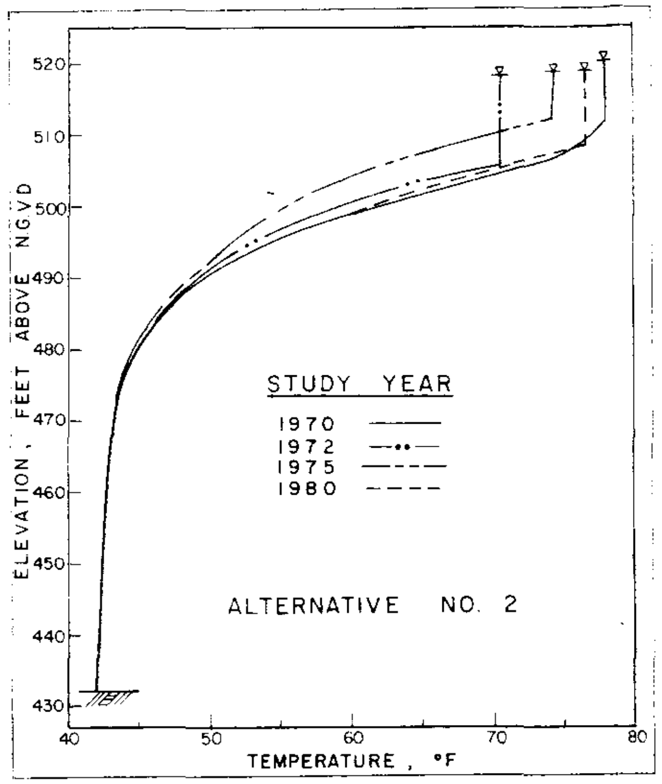

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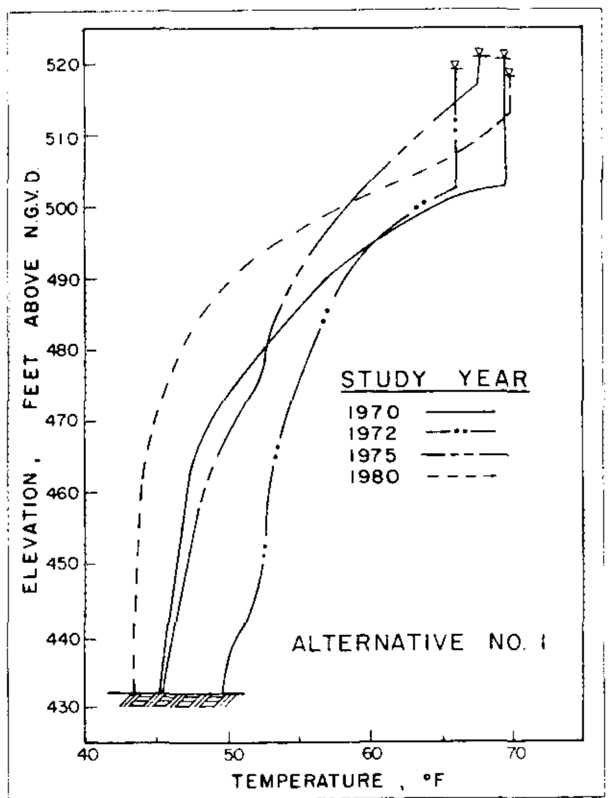

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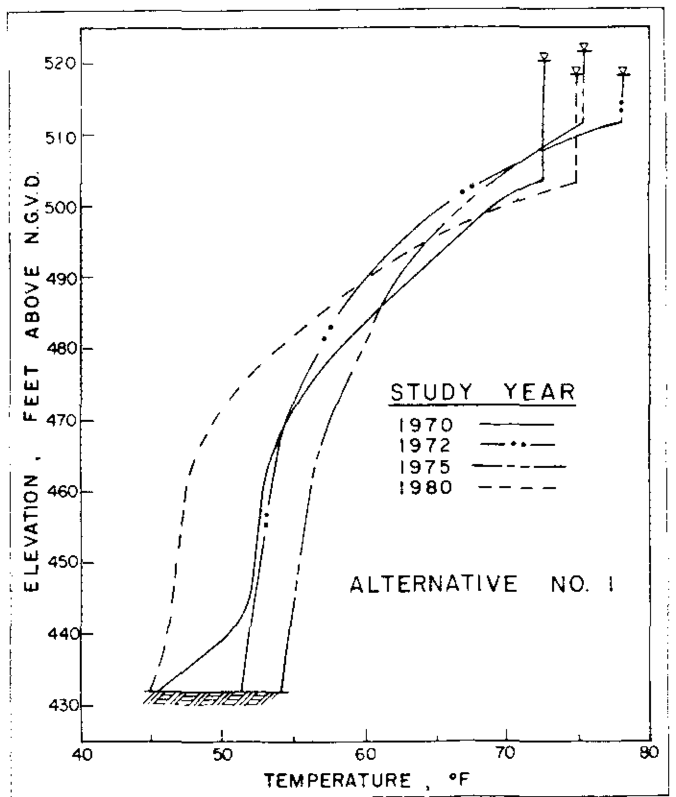

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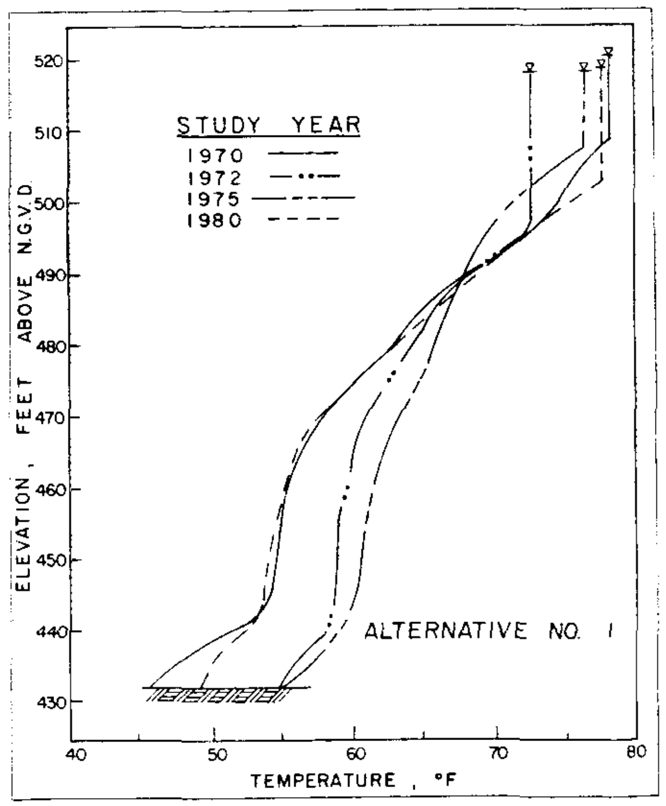

AUGUST 15

DEPARTMENT OF THE ARMY
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WALTHAM, MASS.

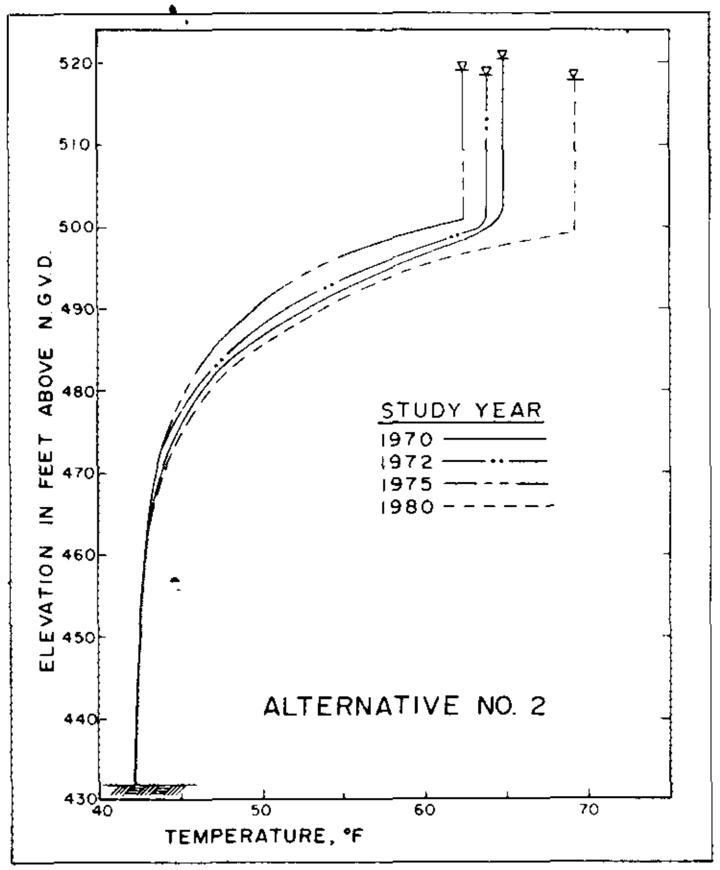
LITTLEVILLE LAKE

HYDROPOWER STUDY

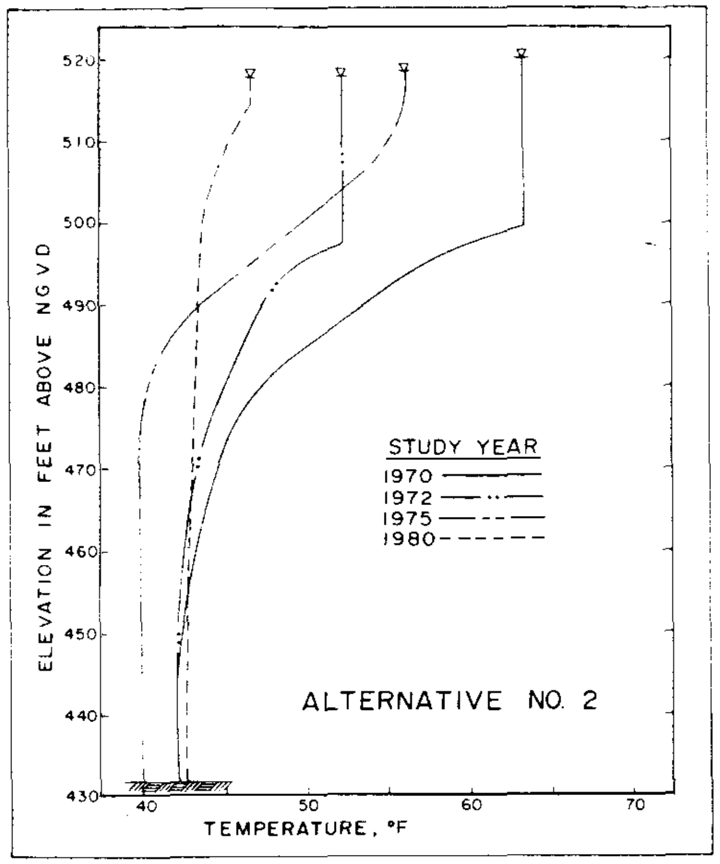
SIMULATED TEMPERATURE PROFILES

JUNE 15 THROUGH AUGUST 15

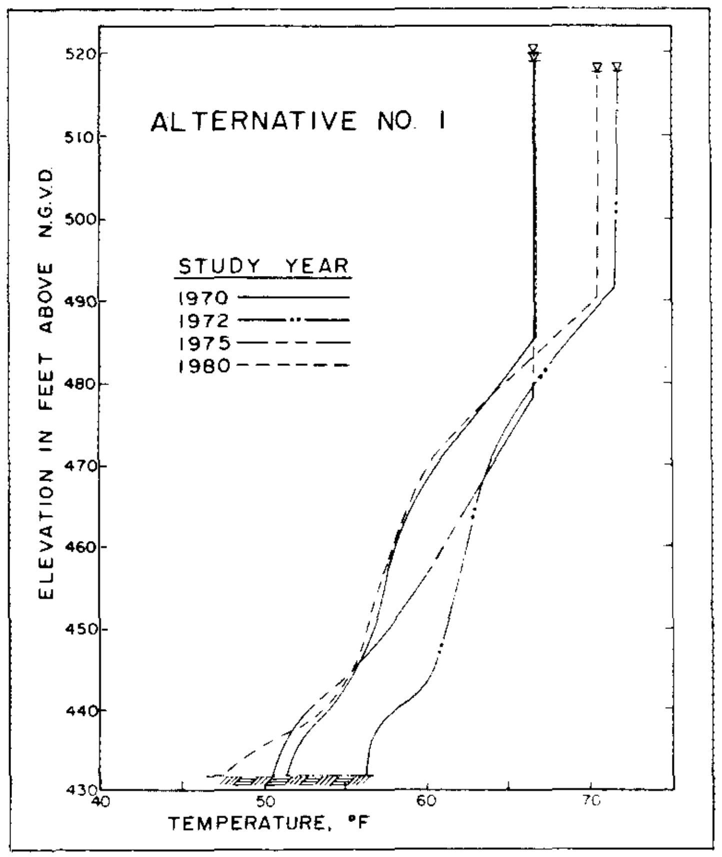
MIDDLE BRANCH WESTFIELD RIVER MASS.



15 SEPTEMBER



15 OCTOBER



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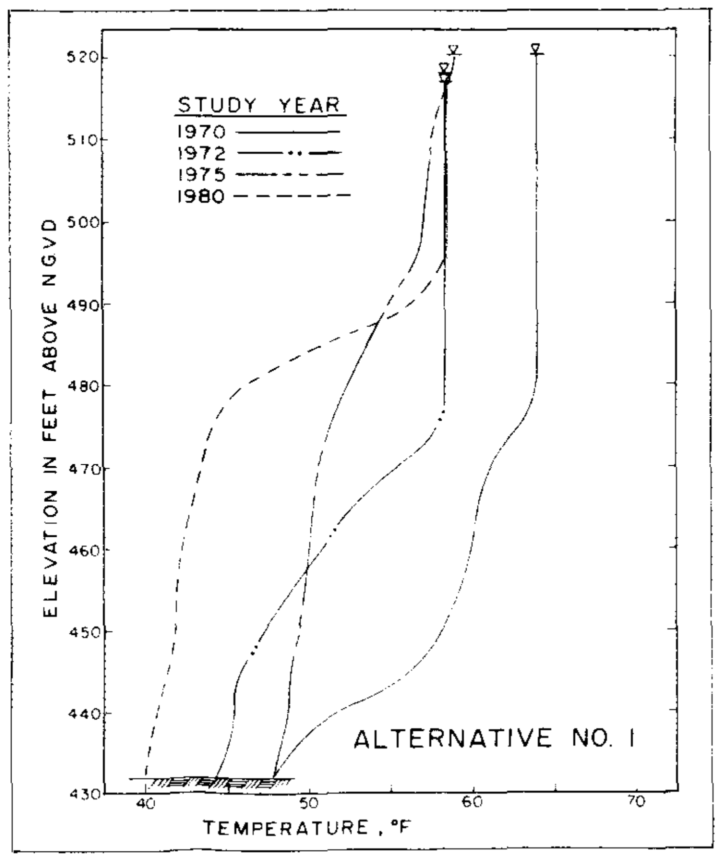


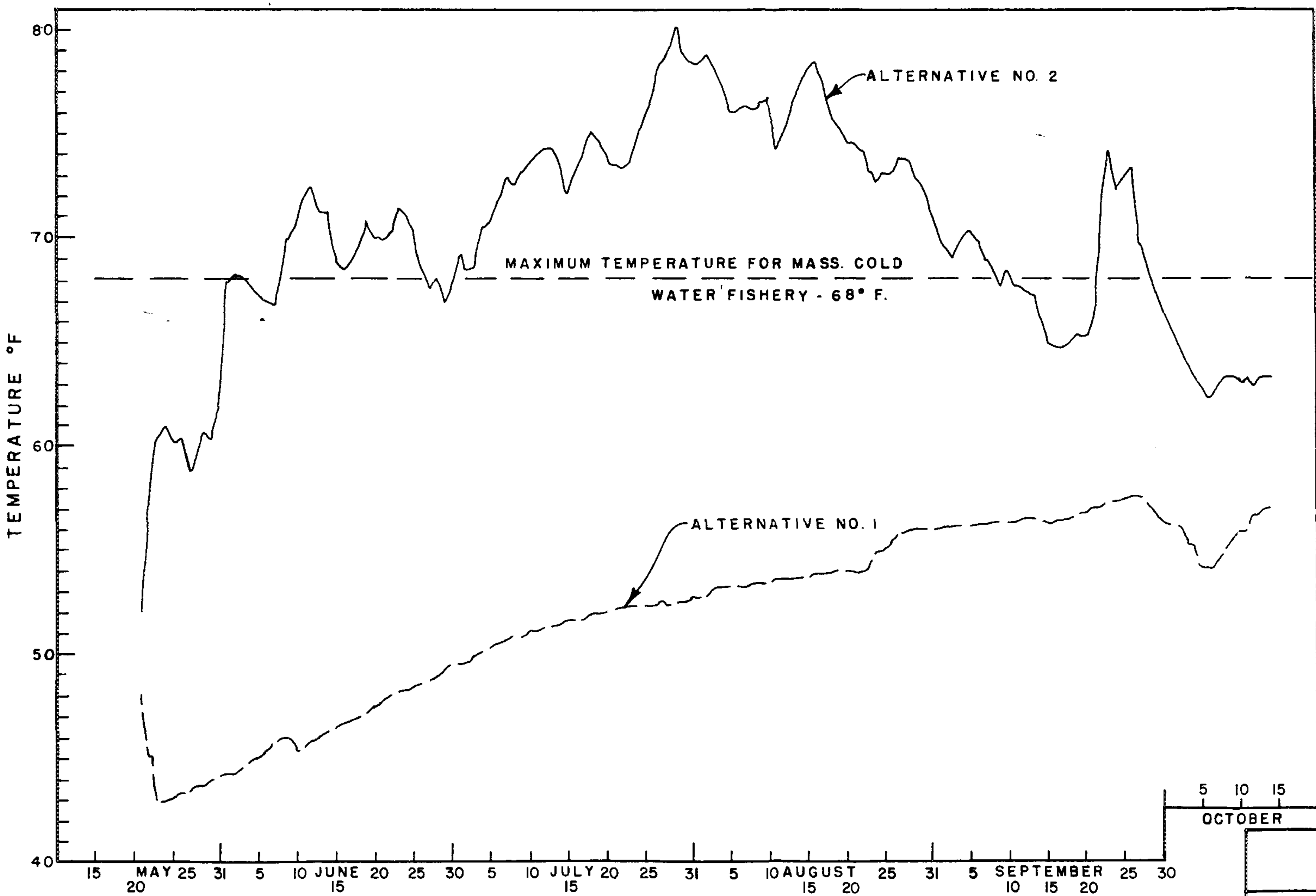
15 OCTOBER

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS

LITTLEVILLE LAKE
HYDROPOWER STUDY
SIMULATED
TEMPERATURE PROFILES
SEPTEMBER 15 THRU OCTOBER 15

MIDDLE BRANCH WESTFIELD RIVER MASSACHUSETTS

PLATE B-12



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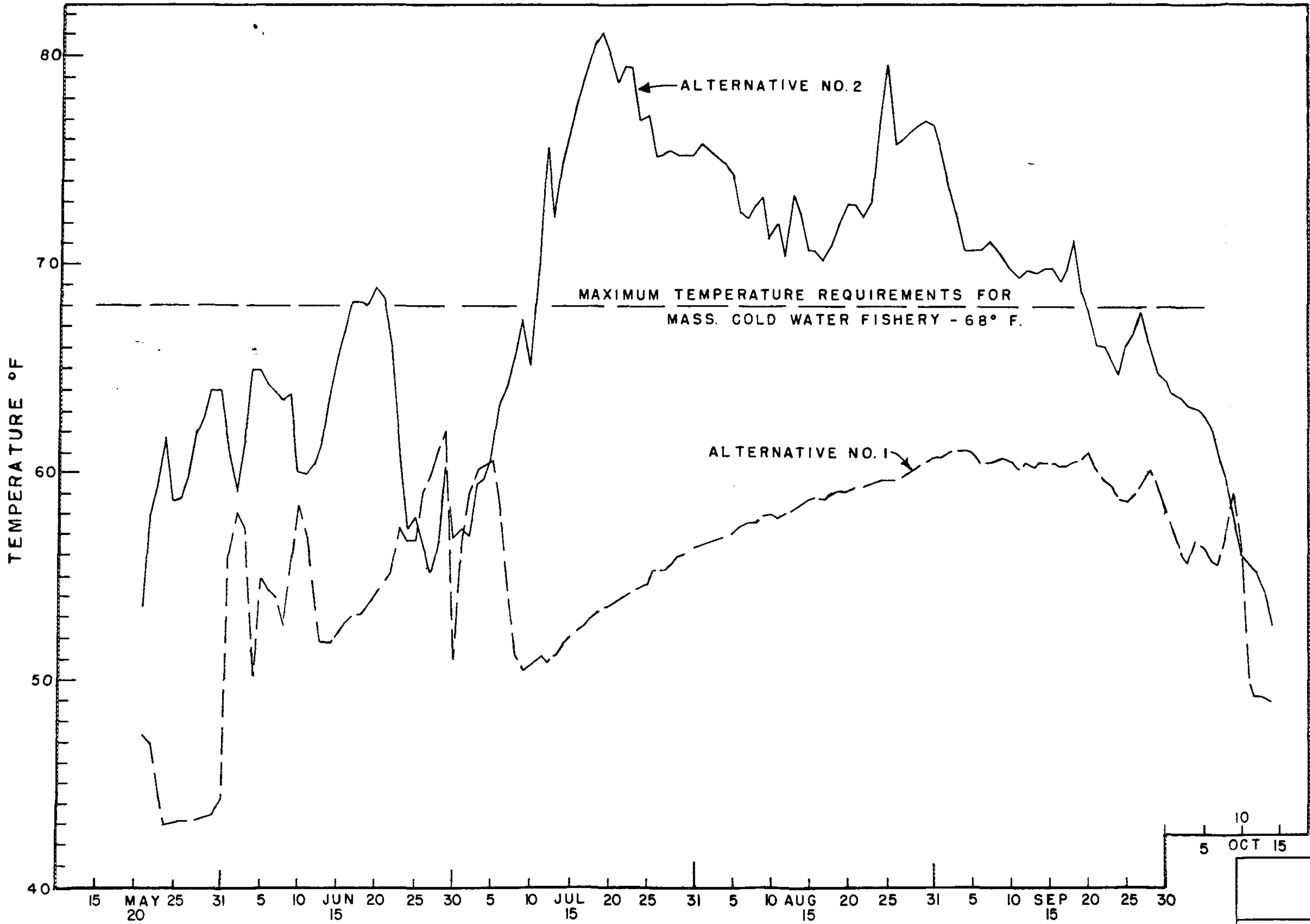
LITTLEVILLE LAKE
HYDROPOWER STUDY
SIMULATED
RELEASE TEMPERATURE
STUDY YEAR 1970

MIDDLE BRANCH WESTFIELD R. MASS.

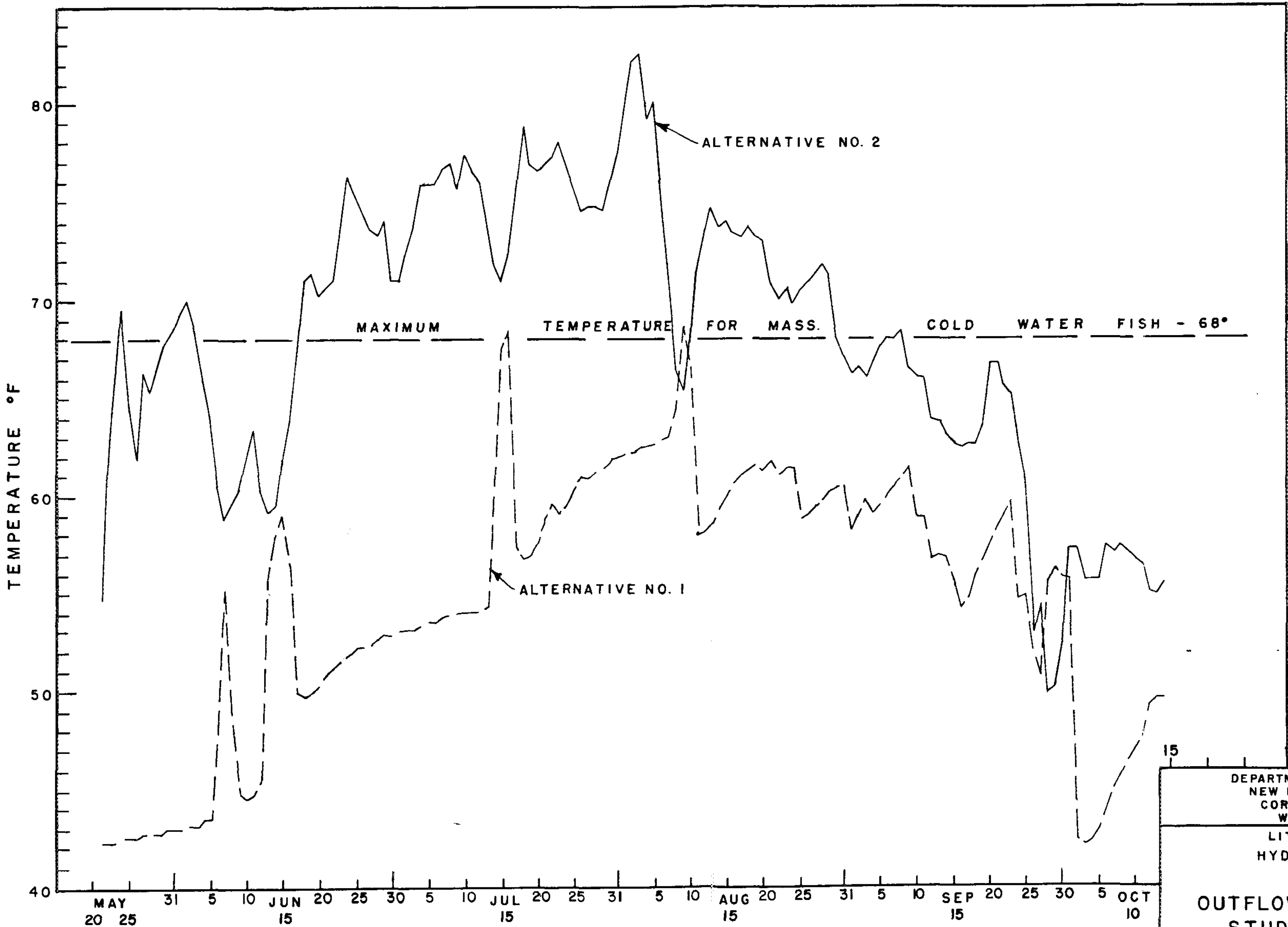


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

LITTLEVILLE LAKE
HYDROPOWER STUDY
SIMULATED
RELEASE TEMPERATURE
STUDY YEAR 1972

M. BRANCH WESTFIELD R. MASS.

PLATE B-14



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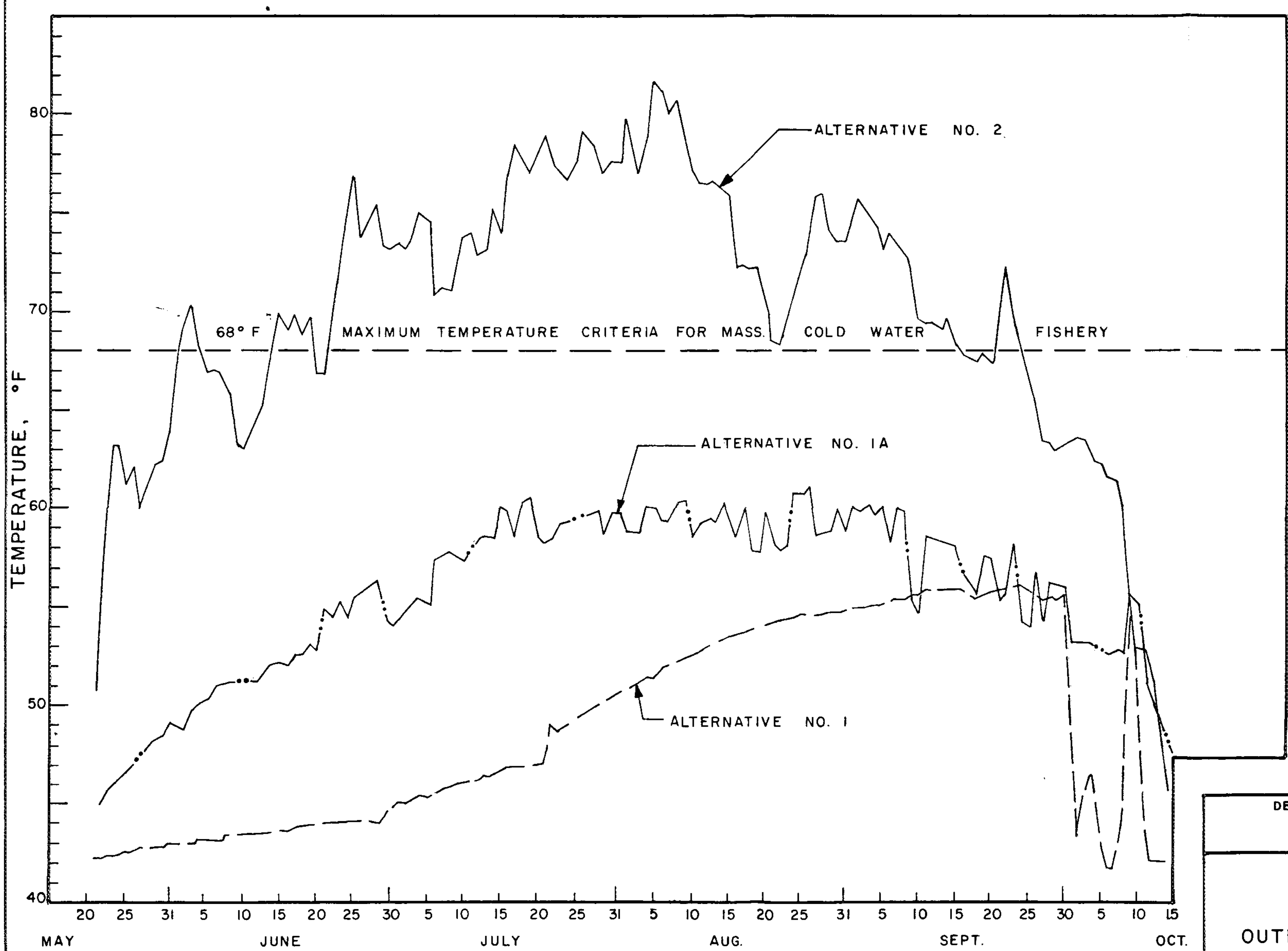
LITTLEVILLE, LAKE
HYDROPOWER STUDY
SIMULATED
OUTFLOW TEMPERATURE
STUDY YEAR 1975

M. BRANCH WESTFIELD R. MASS.

PLATE B-15



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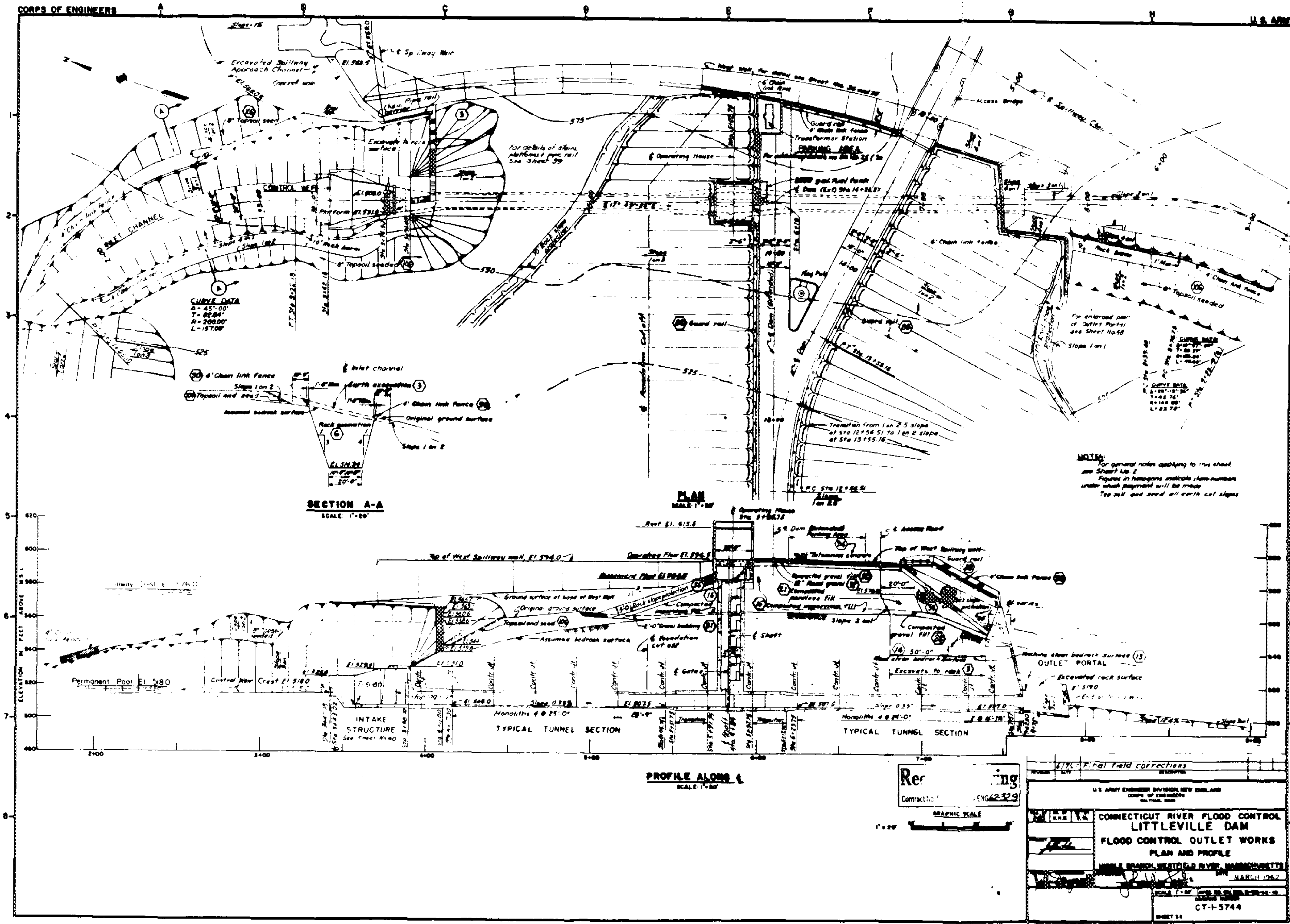
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

LITTLEVILLE LAKE
HYDROPOWER STUDY
SIMULATED
OUTFLOW TEMPERATURE
STUDY YEAR 1980

MIDDLE BRANCH WESTFIELD RIVER MASS.



CORPS OF ENGINEERS
U.S. ARMY
CONTROL WEIR
INLET CHANNEL
CURVE DATA
Δ = 45°-00'
T = 82.84'
R = 200.00'
L = 157.08'
Excavated Spillway Approach Channel
Operating House
PARKING AREA
Transformer Station
Access Bridge
For details of stairs, platforms & pipe rail see Sheet 39
For enlarged plan of Outlet Portal see Sheet No. 48
Transition from 1 on 2.5 slope at Sta 12+56.51 to 1 on 2 slope at Sta 13+55.16
NOTES:
For general notes applying to this sheet, see Sheet No. 2
Figures in hexagons indicate item numbers under which payment will be made
Top soil and seed all earth cut slopes
SECTION A-A
SCALE: 1" = 20'
PLAN
SCALE: 1" = 20'
Inlet channel
Earth excavation
4' Chain link fence
Topsoil and seed
Assumed bedrock surface
Rock excavation
Original ground surface
Slope 1 on 2
Slope 1 on 2
Roof El. 615.5
Top of West Spillway wall, El. 594.0
Operating Floor El. 596.5
Basement Floor El. 566.0
Ground surface at base of West Wall
Original ground surface
Topsoil and seed
Assumed bedrock surface
Permanent Pool El. 519.0
Control Weir Crest El. 518.0
Compacted gravel fill
Compacted pervious fill
Compacted impervious fill
Shaft
Gates
Foundation cut off
OUTLET PORTAL
Excavated rock surface
Excavate to rock
INTAKE STRUCTURE
See Sheet No. 40
TYPICAL TUNNEL SECTION
Monoliths 4 @ 25'-0"
TYPICAL TUNNEL SECTION
PROFILE ALONG ℄
SCALE: 1" = 20'
ELEVATION IN FEET ABOVE M.S.L.
GRAPHIC SCALE
Final field corrections
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
FLOOD CONTROL OUTLET WORKS
PLAN AND PROFILE
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
MARCH 1962
CT-1-5744

PLATE B-17

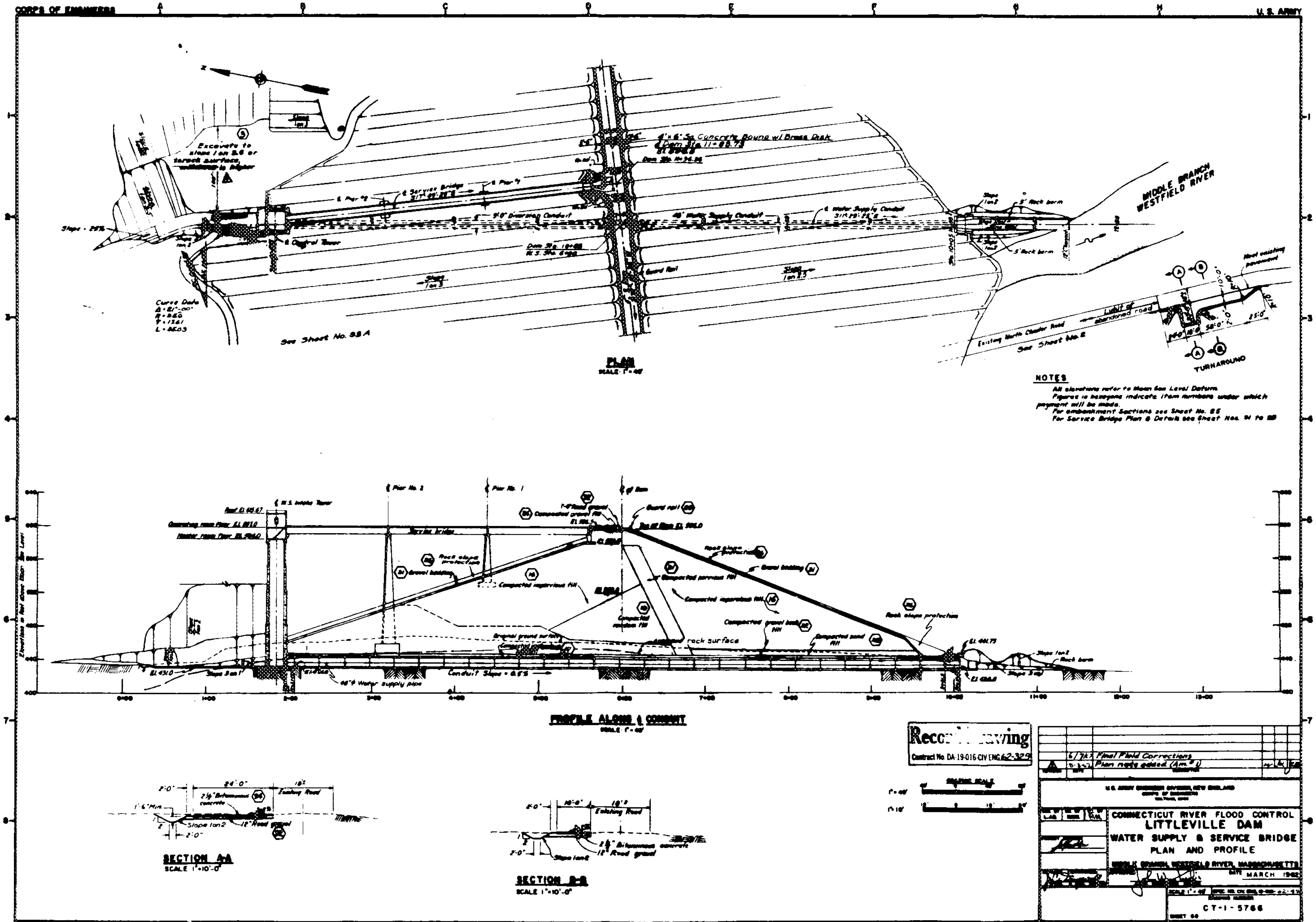

CORPS OF ENGINEERS
U.S. ARMY
Excavate to slope 1 on 3.6 or to rock surface, whichever is higher
4"x 6" Sq. Concrete Bound w/ Brass Disk
Service Bridge
9'-0" Diversion Conduit
48" Water Supply Conduit
Control Tower
Guard Rail
Curve Data
See Sheet No. 93A
PLAN
MIDDLE BRANCH WESTFIELD RIVER
Existing North Chester Road
Limit of abandoned road
See Sheet No. 2
TURNAROUND
NOTES
All elevations refer to Mean Sea Level Datum.
Figures in hexagons indicate item numbers under which payment will be made.
For embankment Sections see Sheet No. 25
For Service Bridge Plan & Details see Sheet Nos. 91 to 99
Pier No. 2
Pier No. 1
Service bridge
Guard rail
Top of Dam El. 585.0
Rock slope protection
Gravel bedding
Compacted impervious fill
Compacted pervious fill
Compacted random fill
Compacted gravel bank fill
Compacted sand fill
Original ground surface
rock surface
Conduit Slope = 0.5%
48" Water supply pipe
Slope 3 on 1
Rock berm
PROFILE ALONG ℄ CONDUIT
SECTION A-A
SCALE 1"=10'-0"
2½" Bituminous concrete
12" Road gravel
Existing Road
Slope 1 on 2
SECTION B-B
SCALE 1"=10'-0"
Record Drawing
Contract No. DA-19-016-CIV ENG 62-329
GRAPHIC SCALE
Final Field Corrections
Plan note added (Am. 1)
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
WATER SUPPLY & SERVICE BRIDGE
PLAN AND PROFILE
MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS
MARCH 1962
CT-1-5766

PLATE B-18

APPENDIX C

ENVIRONMENTAL ASSESSMENT

FINDING OF NO SIGNIFICANT IMPACT

The Environmental Assessment for this project is attached and describes the proposed action, need for the project, alternatives to the project, affected environment and environmental consequences.

Implementation of the proposed project will not require a significant commitment of physical, natural or human resources. Coordination among all parties during the planning process has resulted in the recommended maintenance proposal. The impacts have been outlined in the assessment and are summarized below.

The project would be developed at an existing dam and reservoir with minimal effects on geological, terrestrial, cultural and socioeconomic resources in the project vicinity. The proposed development would be operated as strictly "run of the river", and use existing pool elevations with minimal fluctuations from hydropower operations. Flood control and/or water supply uses would not be affected. Hydropower development would utilize the existing water supply tower and line as a conduit to a new penstock and powerhouse. The multilevel port tower could be utilized to create a year round downstream cold water fishery habitat in place of the existing seasonal one. Impacts to the reservoir's stocked cold water and natural warm water fisheries would be minimal. Approximately 15% of the fish which pass through the installed hydroelectric turbines would not survive. This loss is considered a recreational impact and can be compensated by an appropriate increase in annual stocking effort at the cost to the project. Construction of the penstock and powerhouse would disturb a small portion of the bedrock, soils and grassy habitat downstream of the dam. Such activities would also cause minor siltation in the stream near and downstream of the construction site which would be controlled by appropriate mitigation measures. These impacts would be minor and would not have a significant impact to the project's resources.

There does not appear to be any remaining major environmental problems, conflict or disagreement in implementing the proposed work. I have determined that implementation of the proposed action will not have a significant impact on the human environment and, therefore, will not require an Environmental Impact Statement.

DATE

CARL B. SCIPLE
Colonel, Corps of Engineers
Division Engineer

SUMMARY

Hydropower development is proposed for the existing Corps of Engineers flood control/water supply facility at Littleville Lake in Huntington and Chester, Massachusetts. Two alternative plans have been developed. Alternative "1" would utilize the existing water supply outlet works as a conduit to a new penstock and powerhouse. An existing multilevel port tower would allow water to be withdrawn from four elevations of the 86 ft. deep reservoir. Alternative "2" would utilize the existing flood control outlet works to a new penstock and powerhouse which would continue to withdraw water from the surface of the lake. The facility would be operated strictly as "run-of the river" so that outflows would equal inflow except during times of flood storage or water supply use. Both alternatives would utilize the existing pool elevation of 518 ft. National Geodetic Vertical Datum (NGVD) with daily fluctuations not more than 0.5 foot.

Environmental impacts associated with hydropower development are mainly concerned with the use of Alternative "1" and its effect on the aquatic ecosystem. Water quality modeling studies indicated that the multiport tower can be used to selectively withdraw water from various reservoir elevations to produce a year round cold water fishery habitat downstream of the dam in place of the existing seasonal one. A quality cold water stream fishery would be a desirable feature of this alternative. Withdrawal from the bottom ports would generally reduce the degree of temperature/density stratification in the reservoir and increase the overall water temperature and dissolved oxygen levels below the epilimnion. This would effectively reduce the available cold water fishery storage in the reservoir during the months of July, August and September. Future water quality modeling may "fine tune" the release strategy to reduce this loss and optimize downstream conditions. Any impact to the stocked trout fishery due to the seasonal reduction of cold water storage would be minimal because most of the population is harvested or passed downstream by the time reservoir waters become stratified. Little impact is anticipated to the existing warm water fishery. It is expected that under optimal design/operating conditions no more than 15% of the trout that pass through the turbines would not survive. This is considered a recreational impact which can be compensated by annual increases in fish stocking.

Alternative "2" would utilize the existing outflow operation and would not change existing water quality conditions in the reservoir or the downstream aquatic habitats. The downstream riverine habitat would continue as a seasonal cold water fishery offering little trout fishing opportunity during the summer months. Turbine mortality would occur as described in Alternative "1".

Construction of the penstock and powerhouse under both alternatives would disturb a small portion of the bedrock, soils and grassy habitat downstream of the dam. Such activities would also cause minor siltation in the stream habitat downstream of the construction site which would be controlled by appropriate mitigation measures. Thus, such impacts will be minor and would not have any significant impact for the geological, terrestrial, cultural or socioeconomic resources in the project vicinity.

ENVIRONMENTAL ASSESSMENT

PROJECT DESCRIPTION

The development of hydroelectric power is proposed for Littleville Lake, an existing Corps of Engineers flood control-water supply dam and reservoir located in Huntington and Chester, Massachusetts. The plans for development are considered to be compatible with both authorized uses of the Federal project.

The proposed plan would utilize the existing water supply conduit as a penstock. Flows would be diverted to a new powerhouse located approximately 200 feet downstream from the toe of the dam and discharged to the Middle Branch of the Westfield River. The powerhouse would contain a single horizontal Francis turbine with an installed capacity of 800 kilowatts (kw). This plant would have a net head of 79 feet and is capable of generating about 2,674 megawatt hours (mwh) per year of energy and has a design discharge of 125 cfs. The water supply wet well has four intake portals which can be used to withdraw water from various elevations of the reservoir. Releases are proposed to be managed to develop a year round downstream cold water fishery habitat in place of the existing seasonal one.

The project would be operated strictly as a "run of the river" facility and would utilize the present pool elevation of 518 feet National Geodetic Vertical Datum (NGVD). Hydropower operations would utilize flow between 82 and 140 cubic feet per second (cfs). When flows are below 82 cfs hydropower operations would be shut down. This would occur throughout most of the summer months. Outflows from the reservoir would continue to be withdrawn from the multiport tower and would be equal in magnitude to the inflows. A more detailed description may be found in Appendix A of this survey report.

NEED FOR THE PROJECT

The New England region is highly dependent on oil generated electricity. In 1981 over 65 percent of the electricity generated by the New England Power Company and the Boston Edison Company, two of the three largest producers of electricity in the region, was oil generated. In 1982 the New England Power Company reduced the amount of oil produced electricity to 25 percent of the total produced by converting several plants to coal fueled. The conversion of oil fired plants to coal is planned for many utilities but pollution standards limit the amount of conversion possible and require the use of more expensive low sulphur coal.

At Littleville Lake, the existing flood control-water supply facility operates as a run of the river operation where the lake's outflow is equal to the inflow except during periods of flood control operations. This outflow has a potential energy which is presently not harnessed. Since hydropower generating facilities do not use or burn fuels their operation is far cheaper and generally more environmentally acceptable to the public than fossil fueled plants. At the authorization of Congress, the New England Division has been requested to examine existing facilities in the Connecticut

River Basin to determine if modifications are feasible to allow the development of hydropower, flood control and water supply in a cost effective, environmentally acceptable manner.

The proposed project would generate about 2,674 megawatt hours of electricity per year which would provide enough energy to supply about 445 homes, based on an average annual residential usage of 500 kwh per month. At 65 percent efficiency, this represents an annual savings of 2,754 barrels of oil which would be needed to provide the same amount of electrical energy.

ALTERNATIVES

Two alternative plans for hydropower development at Littleville Lake were considered. The characteristics of each alternative are summarized in the top portion of Table C-1. Alternative 1 as described in the project description would make use of the existing water supply outlet works as a conduit to the powerhouse. About eighty feet of new penstock would have to be added to connect the water supply line to the powerhouse. Water for generating power would be withdrawn from any two of four elevations in the reservoir. Alternative 2 would utilize the existing flood control outlet works and add a new 500 foot penstock to tie into a new powerhouse. Water would be withdrawn from the reservoir surface as is currently done. Both alternatives would be run of the river projects and would utilize the existing power pool elevation of 518 feet NGVD. The higher net design head of Alternative 2 gives slightly more power benefits than Alternative 1.

The impacts of each alternative are summarized in the lower portion of Table C-1. Construction of the new penstock and powerhouse would disrupt the bedrock, soils and grassy terrestrial habitat in the downstream area. Such activities would also cause minor siltation in the Middle Branch of the Westfield River. A longer construction period would be associated with Alternative 2 because of the longer penstock and outlet works modifications. The major difference between the two alternatives would be associated with where the water is withdrawn from the reservoir and its effect downstream. Water quality modeling studies indicated that use of the water supply multiport tower can be managed to create a downstream year round coldwater fishery habitat in place of the existing seasonal one. A quality cold water stream fishery during the summer months would be an added desirable feature of this alternative. The increased mixing and flushing of the reservoir at depth would increase the reservoir's dissolved oxygen and water temperature. The resulting habitat changes may allow increased stocking in one or both of these areas and thereby provide increased recreational fishery use. Downstream access to recreational fishermen would have to be provided by the State if this area is stocked. Implementation of Alternative 2 would not change the existing reservoir and downstream habitats. Prehistorical and Historical Cultural resources would not be affected by either alternative. Both alternatives have construction associated short term socio-economic impacts, such as temporary increases in construction employment, noise and dust. As indicated earlier, both alternatives would provide a renewable energy resource which would supply electrical power to about 445 homes in the area.

Table C-1. Characteristics and Impacts of the Proposed Alternatives of Power Development at Littleville Lake, Massachusetts

	Alternative "1"	Alternative "2"	No Action
Project Characteristics			
Outlet Works	Water supply tower	Flood control gate	-
Penstock	Water supply conduit & 80 ft new penstock.	500 ft of new penstock.	-
Powerhouse	1/8 acre of downstream area	1/8 acre of downstream area	-
Turbine	Horizontal Francis Unit	Horizontal Francis Unit	-
Installed Capacity	800 Kilowatts (kw)	1000 kw	-
Net Design Head	79 ft	86 ft	-
Design Discharge	143 cfs	164 cfs	-
Energy Generation	2674 megawatt hours (mwh)	2911 mwh	-
Project Impacts			
Geology	Removal of soils & bedrock from downstream area.	Removal of soils & bedrock from downstream area.	No impact
Aquatic Ecosystem			
Reservoir Habitat	Reduce density stratification Increase water temperature and dissolved oxygen at depth.	No impact	No impact
Downstream Habitat	Create year round cold water fishery habitat.	No impact	No impact
Turbine Mortality	15% of fish which pass during hydropower operation.	15% of fish which pass during hydropower operation.	No impact
Construction Impacts	Minor siltation in downstream	Minor siltation in downstream area.	No impact
Terrestrial Ecosystem	Minor disruption of downstream grassy habitat.	Minor disruption of downstream grassy habitat.	No impact
Recreation Resources	Potential for increase in fish stocking.	No impact.	No impact
Cultural Resources	No impact	No impact.	No impact
Socio Economic Resources	Minor increase in noise, dust, temporary construction jobs ~~power benefits~~ 445 homes.	Minor increase in noise, dust, construction jobs ~~power benefits~~ 445 homes.	No impact

No action would mean that hydropower would not be developed at Littleville Lake and therefore no impact to its resources would occur. The electrical power that would have been supplied by the proposed facility would continue to be provided by oil or coal generated plants.

ENVIRONMENTAL SETTING

General

The Westfield River Basin is located in Berkshire, Franklin, Hampden and Hampshire Counties, Massachusetts and a small portion of Hartford County, Connecticut (see Plate 1). The basin has a total drainage area of 517 square miles and is the fifth largest subdrainage of the Connecticut River.

The Littleville Dam is located along the Middle Branch of the Westfield River about one mile upstream of its confluence with the main stem in the towns of Huntington and Chester (see Plate A-1, Appendix A). The extent of the project area is shown in Plate 2.

Topography

The Westfield River Basin, in general, consists of a maturely dissected upland. Steep-sloped rocky hills are separated by narrow valleys and are drained by many small streams. Watershed elevations range from 2,505 feet NGVD at the headwaters of the Westfield River to about 40 feet at the river's confluence with the Connecticut River. The Middle Branch of the Westfield River falls 1,100 feet over its 16 mile length at an average gradient of nearly 70 feet per stream mile. Elevations near the project area range from 1,296 feet at the top of Goss Hill (about 2.3 miles north of the damsite) to 432 feet upstream of the damsite.

Geology

The Westfield River flows in a deep, pre-glacial valley in the New England upland section of western Massachusetts. The bedrock hills and ridges are generally blanketed by a thin cover of glacial till, consisting of unsorted materials deposited directly from the glacier and ranging in gradation from clay to boulders. The bottom of most of the main valleys have been deeply filled by deposits of till and outwash. The outwash deposits, which consist of variable, roughly stratified sand, silt and gravel form narrow flood plains along valley bottoms and terraces on the valley walls. Bedrock outcrops are common through the thin till cover on the upper slopes and tops of the hills. In the valleys, bedrock is exposed only where the rivers have cut through the till and outwash. The bedrock of the region consists of a series of folded Palezoic crystalline rocks, mostly mica schist, of several formations. The folds trend generally north-south.

Climatology

Annual air temperatures recorded at nearby Knightville Dam for the past 23 years average 45.6^{o} F. Although extremes such as -30^{o} F and 102^{o} F have been recorded, the average January temperature was 23^{o} F; whereas, the average July temperature is 69° F. There is an average of 95 frost free days per year most of which occur between June 3 and September 9.

Annual precipitation averages about 46 inches and is fairly uniform throughout the year. Variations over a 44 year period were as low as 32 inches to as high as 67 inches. Annual snowfall averages 56 inches and intermittently remain on the ground from December through Mid-April.

Aquatic Ecosystem

Littleville Lake

General

The 1965 construction of Littleville Dam across the Middle Branch of the Westfield River created a 275-acre lake with an average depth of about 54 feet. During nonflood periods the reservoir is normally kept at a target elevation of 518 feet and contains a volume of about 9,400 acre-feet. The city of Springfield owns the water space between elevation 432 feet and 518 feet under a 1967 agreement with the Corps of Engineers. Because of potential use as public water supply the reservoir bottom was cleared. Besides input from the Middle Branch of the Westfield River, Littleville Lake also receives inflows from four tributaries, including Winchell Brook, which drain from upland wetlands well above the lake elevation.

Water levels fluctuate both daily and seasonally depending on the precipitation. Daily fluctuations rarely exceed one foot. Seasonal fluctuations, however, are more variable. Significant storage, i.e., at least 1 inch of runoff which is equivalent to 2,790 acre-feet of flood water, has occurred 17 times since operation began in 1965. The highest storage on record reached an elevation of 548.6 feet in March 1977. About 46 percent of the storage capacity was used in this event for 3.8 inches of runoff. After such a storage, water levels return to normal in a week's time.

Water Quality

The Middle Branch of the Westfield River above Littleville Lake is rated Class A by the Massachusetts Water Resources Commission and as such is designated for use as a public water supply. A designation as to whether this section of the Westfield River is a warm water or a cold water fishery has not been made. Technical requirements for warm water fisheries include a minimum dissolved oxygen concentration (DO) of 5 mg/l and a maximum temperature of 83° F. For cold water fisheries the minimum DO is 6 mg/l and the maximum temperature is 68° F. Other technical requirements for Class A warm and cold water fisheries include total coliform bacteria not to exceed a log mean of 50 per 100 ml for a set of samples during any monthly sampling period, total dissolved solids not to exceed 500 mg/l, chlorides not to exceed 250 mg/l, sulfates not to exceed 250 mg/l, and nitrate not to exceed 10 mg/l as nitrogen. In addition, there shall be no substances in concentration that: produce objectionable color, odor or turbidity; exceed the limits necessary to control eutrophication; or exceed the recommended limits on the most sensitive receiving the water use.

There are no significant point-source discharges upstream from Littleville Lake, and the water quality at the project generally meets the requirements of its Class A designation. The water quality data collected by the NED water quality lab since 1970 shows no violation of chloride, sulfate, nitrate or total solids standards; only very rare dissolved oxygen violations, except in the hypolimnion; some solid form violations; and frequent pH and temperature violations. Nutrient analyses show relatively moderate levels of nitrogen but low levels of phosphorus. Heavy metals concentrations are generally low to undetectable except for iron, manganese and zinc. The sources of these metals upstream from the project are unknown. However, iron and manganese levels are increased during the summer by reduction reactions occurring in the hypolimnion in Littleville Lake.

The Littleville Reservoir is a dimictic lake that stratifies during the summer and winter months followed by turnover or mixing in the fall and spring. Typical temperature profiles showing the more marked summer stratification are exhibited in Plates B-11 and B-12 of Appendix B. In general, stratification begins in May and becomes more prominent during June. By July and August, the strata are clearly defined with an upper zone (epilimnion) about 5-10 feet thick, a middle zone (metalimnion) ranging from 10-20 feet in thickness, and a lower zone (hypolimnion) extending 50-70 feet above the bottom. Water temperatures during August generally range from 42-44^{o} F near the bottom and to 78^{o} F at the surface. This stratification causes a decrease in the dissolved oxygen (DO) in the hypolimnion by July. Minimum DO values occur in September. Values below the 20-25 foot depth are generally less than 5 parts per million (ppm), which is considered stressful for coldwater fish such as trout. The fall turnover usually occurs by October so that the oxygen levels in the lower stratum are generally above 5 ppm and close to saturation.

Fisheries

Littleville Lake and the Middle Branch, upstream of the lake, provide habitat for a variety of cold water and warmer species. Table C-2 indicates common species collected during recent surveys conducted by the Massachusetts Division of Fisheries and Wildlife (MDFW). Littleville Lake is managed by the MDFW as a "put and take" trout fishery. Approximately 8,000-10,000 9-12 inch sized, individuals are annually stocked. Stocked species mainly consist of rainbow and brown trout, but vary with their annual availability from the state's hatcheries.

The listed warm water species have persisted in the lake despite reclamation in 1965. Because of the heavy fishing pressure from April through June, competition by warm water species has not been a significant problem. Natural reproduction of lake residents has not been documented. Halliwell (1978) indicated that the river water temperatures upstream of the lake remain sufficiently cold to favor trout survival. However, natural reproduction in nearby tributaries is not sufficient to supply the needs of the current fishing demands.

Table C-2. Fisheries of the Middle Branch of the Westfield River, Massachusetts

	Common Name	Scientific Name	Upstream of Littleville Lake[1]	Littleville Lake[2]	Downstream of Littleville Lake[1]
Game					
	Brown trout	*Salmo trutta*	X		
	Brook trout	*Salvelinus fontinalis*	X		
	Rainbow trout	*Salvelinus gairdneri*	X	X	
	Largemouth bass	*Micropterus salmoides*		X	
	Smallmouth bass	*Micropterus dolomieui*			X
Rough					
	White sucker	*Catostomus commersoni*	X	X	X
Forage					
	Blacknose dace	*Rhinichthys atratulus*	X		
	Longnose dace	*Rhinichthys cataractae*	X		
	Slimy sculpin	*Cottus cognatus*	X		
	Creek chubb	*Semotilus atromaculatus*	X		
	Fallfish	*Semotilus corporalis*			X
	Common shiner	*Notropis cornutus*	X	X	
Warmwater					
	Yellow perch	*Perca flavescens*		X	
	Golden shiner	*Notemigonus crysoleucas*		X	
	Chain pickerel	*Esox niger*		X	
	Brown bullhead	*Ictalurus nebulosus*		X	X
	Pumpkinseed	*Lepomis gibbosus*		X	

1 Modified from Halliwell (1978)
2 1980 data provided by MDFW (1982)

As mentioned above, trout are cold water species that generally require water temperatures below 68° F and dissolved oxygen levels of at least 5-6 mg/l. The lake provides these requirements until early summer when the fish are found in the top 55 feet of the water column. As the surface water warms in July to above 70° F, the fish are found mostly at depths ranging from 30 to 55 feet (MDFW, personal communication).

Middle Branch Downstream of Littleville Lake

General

Generally, the Middle Branch riverine habitat continues downstream for approximately one mile to its confluence with the East Branch of the Westfield River. This section is generally 30-40 feet in width, one to two feet or more in depth and generally exposed. The bottom is primarily composed of boulders, rubble, and bedrock with some sand and gravel.

Water Quality

Downstream from Littleville Lake to the confluence with the Westfield River, the Middle Branch is rated Class B, seasonal cold water fishery. Requirements for these waters include a minimum dissolved oxygen concentration of 6 mg/l, a maximum temperature of 68° F, pH in the range 6.5 to 8.0, and fecal coliform bacteria counts not to exceed a log mean of 200 per 100 ml.

The releases of warmed surface waters from the flood control weir elevate the downstream water temperatures during summer to nearly 80° F with an average of 75° F (Massachusetts Division of Water Pollution Control (MDWPC), 1978). Dissolved oxygen values during mid-summer ranged from 7.0 to 9.0 mg/l with an average of 8.3 mg/l. Notwithstanding the summer temperatures, the MDWPC has indicated that this section of the Middle Branch has "very high water quality" with little input from pollution sources. Analyses of grab samples exhibited a diverse macroinvertebrate benthic community which for the most part was considered intolerant to pollution.

Fisheries

The habitat downstream of Littleville Lake was surveyed in 1977 by the MDFW (Halliwell, 1978). Species collected included small-mouthed bass, white sucker, fallfish and brown bullhead (Table C-2). The size of most smallmouth bass were sublegal (less than 10"), affording little potential as a sport fishery. No trout were collected in the area because of the warm water releases from the reservoir. In addition to these species found by Halliwell, a previous July 1952 (Mullan, 1952) sampling, prior to the existence of the present Littleville dam, indicated the presence of longnosed dace, black-nosed dace, common shiner, creek chubs, brook and brown trout, darters, and bluegills. Water temperatures of 78-79° F were recorded in the river below the "former" Littleville dam during July.

The area is occasionally stocked with 2,000 trout during spring. The area does provide suitable trout habitat for most of the year. However, cold water fishery temperature requirements generally are not met from June 30 to about September 15 of an average year. The MDFW indicated that a large portion of this area of the river is heavily posted by the local landowners to keep out fishermen because of past litter problems. Fishing opportunities in terms of available resources and public access are limited.

Anadromous Fisheries

The Westfield River was once a migration pathway for Atlantic Salmon. Since the industrial age, degradation of water quality near and below its confluence with the Connecticut River and the installation of 13 dams along the three branches precluded annual spawning runs in this reach of the river. A restoration program, currently planned, would restore available reaches for salmon up to the second dam on the Westfield River's main stem. The planned restoration is well below Littleville Reservoir and, therefore, fish passage facilities would not be required at this time.

Terrestrial Ecosystem

Vegetation

Table C-3 indicates the land cover types of the lands held in fee surrounding Littleville Lake based on an intensive 1977 forest inventory. The lake plus the surrounding forest encompasses almost 90% of the entire Federal property. Open woodland and fields are only 9% of this while the remainder of the property includes flood control structures, operation and maintenance areas, access roads and boat ramps. Prior to filling the pool, the reservoir was cleared to elevation 523 feet where the tree line now exists. Below this elevation, perennial grasses, ferns and rock surround the shoreline.

Three known soil associations occur in the study area: (1) Monroe soil - shallow, occurring on steep slopes; (2) Blanford soil - deep, well drained and less stony occurring on plateaus and ridges; and (3) Woodbridge soil - moderately well drained occurring on the lower slopes.

Most of the forest is comprised of second growth northern hardwood and hemlock-hardwood cover types. Common hardwood species include American beech (Fagus grandifolia), sugar maple (Acer saccharum), red maple (Acer rubrum), yellow birch (Betula alleghaniensis), paper birch (Betula papyrifera), white birch (Betula populifolia), red oak (Quercus rubra), American elm (Ulmus americana), and white ash (Fraximus americana). Dominant softwoods include Eastern hemlock (Tsuga canadensis), white pine (Pinus stobus) and red pine (Pinus resinosa). A variety of common northeastern ferns, shrubs and wildflowers occur in the understory.

Forest stands are generally even aged with nearly 60% mature to over mature or mature within 5 years of rotation. Approximately 14% of the forest in the project area is of pole timber size. Improvements to the growing stock by such techniques as plantings, thinning, pruning and improvement cutting have been proposed in Forest Management Plan, Appendix B of the Littleville Lake Master Plan. Special management techniques are also being proposed to increase habitat diversity for enhancement of wildlife.

TABLE C-3

LAND COVER TYPES SURROUNDING LITTLEVILLE LAKE*

Land Cover Type	Area (Acres)	% Total Area
Forest	1190	73
Lake	273	16
Open Woodland	82	5
Field	61	4
Other**	34	2
Total	1640	100

*Excerpted from Forest Management Plan, Master Plan, Appendix B, Littleville Lake, Huntington, Massachusetts, February 1978, Army Corps of Engineers.

**Flood control structures, operation and maintenance areas, access roads, parking lots and boat ramps.

Wildlife

The forest and regenerating fields serve as habitat for a variety of resident and migrating wildlife. White-tailed deer (*Odocoileus virginianus*) is the only "big game" species in the area. Typical upland species include varying hare (*Lepus americanus*), cottontail rabbit (*Sylvilagus transitionalis*), gray squirrel (*Sciurus carolinensis*), red squirrel (*Tamiasciurus hudsonicus*), racoon (*Procyon lotor*), ruffed grouse (*Bonasa umbellus*), and American woodcock (*Philohela minor*). A small number of furbearers such as muskrat (*Ondatra Zibethica*), mink (*Mustela vison*), and beaver (*Castor canadensis*) may also occur in the project area. The woodlands provide food and habitat for a wild turkey population, especially during late winter and spring. Littleville Lake is also used as a resting area for migrating waterfowl. However, the food, nesting and brood-rearing requirements at the lake are limited. A 1973-1974 attempt to establish a permanent breeding ground for Canada geese was not successful. A variety of other typical northeastern small mammals, avifauna, reptiles and invertebrates also inhabit the area.

Previous regulations governing activities at Littleville Lake, implemented by the City of Springfield, precluded hunting and trapping on project lands. Recently, hunting has been restored but may be restricted if the lake is used for water supply purposes.

Rare and Endangered Species

Currently, there are no Federally listed threatened or endangered species residing in the project area (U.S. Fish and Wildlife Service, personal communication). However, the Commonwealth of Massachusetts has compiled a list of State rare and local species which may or may not occur in the area. These species are not Federally listed as threatened or endangered, nor are they proposed.

The Massachusetts State ornithologist indicates that the area may serve as habitat for the great blue heron (Ardea herodias), the Cooper's hawk (Accipiter cooperii), and the sharp-shinned hawk (Accipiter sciatus). Also, the lake chub (Couesius plumbeus), which only occurs in the Westfield River Basin, is currently designated as a species of "Special Consideration." There are a number of mammals, reptiles and amphibians which are also given this designation. The Massachusetts Natural Heritage Program has indicated that no rare plants have been presently recorded in the project area.

Recreational Resources

Littleville Lake is presently operated for water supply and flood control purposes and consists of a 275 acre impoundment with a maximum depth, at the normal water supply pool elevation of 518 feet NGVD, of 86 feet at the dam, and an average depth of approximately 54 feet. Fishing is the primary recreational activity that takes place on the lake, and along the shore in designated locations. Sport fishing, primarily for trout, accounts for about 39 percent of the total recreational visitation at Littleville Lake, while sightseeing, mostly at the dam, accounts for about 52 percent. Most of the shoreline fishing takes place in the vicinity of the two boat launching ramps at the Huntington Access Area near the dam, and at the Dayville Access Area at the upper end of the lake. Over the past six years sport fishing has averaged about 28,000 visitor days annually. Approximately 60 percent of this is recorded at the Huntington Access Area and about 40 percent at the Dayville Access Area. Littleville is considered a cold water fishery and is stocked with trout by the Massachusetts Division of Fisheries and Wildlife. Trout fishing downstream of Littleville Dam in the Middle Branch of the Westfield River is limited due to warm water releases from the reservoir during summer and the reduced access caused by the posting by local landowners.

Since the lake serves as a water supply reservoir, most recreational activities are not allowed, and consequently no facilities, except for the two boat ramps, are provided. Other than sightseeing at the dam and fishing, the only other recreational uses occurring on project lands are small amounts of hunting, picnicking, boating, snowmobiling and trail bike riding. Visitation to the project has been relatively stable over the past ten years with no major increases or decreases from year to year, although the total fishing visitation has been gradually declining since 1976.

Archaelogical/Historic Resources

Few prehistoric sites are reported in the Westfield valley above its confluence with the Connecticut.Reconnaissance level survey at tributaries of the West Branch during the mid-1970's failed to discover any prehistoric sites. Two areas on the East Branch are reported to contain sites, and are currently under survey as part of a cultural resource reconnaissance at Knightville Dam, but the Middle Branch has never been subjected to professional archaeological survey. The apparent scarcity of sites within the drainage is probably due more to the small amount of survey performed to date, rather than a true absence of prehistoric inhabitants. Evidence of intensive and repeated settlement at the confluence with the Connecticut and natural characteristics of the valley as a travel route indicate that river terraces throughout the valley have high potential for presence of small camp sites dating throughout the prehistoric period.

Examination of soil, maps, coupled with surface examination of the Littleville Lake area reveals that the flood plain terrace of the Middle Branch had high potential for prehistoric occupation. However, most of this terrace is now permanently inundated, and was apparently stripped and grubbed prior to reservoir construction, destroying or rendering inaccessible any sites below elevation 518. Only near the upper end of the project, near Dayville does any of this terrace remain intact. Limited subsurface testing undertaken in 1981 at the Dayville Access Area parking lot revealed no prehistoric material, but exhibited undisturbed soil conditions.

Examination of historic period maps revealed that prior to dam construction, the area contained 2 store sites, 1 blacksmith site, 3 school sites, 1 church site, 2 cemetery sites, 9 mill sites, and over 30 dwelling sites. Many of them had standing structures which were removed for the project, and burials were relocated from both cemeteries. Most of the above sites dated from at least as early as 1870.

Unfortunately, dam construction and clearing for the permanent pool obliterated nearly all of the features noted above. Sites remaining above 518 feet NGVD include a school (later a house), 2 shoe manufacturers, and a sawmill at Dayville, the Fisk Cemetery location, and sites of 9 dwellings and associated outbuildings above the area of Littleville village. Most of these were bulldozed and filled at the time of dam construction.

Socioeconomic Resources

Overview

The Westfield River Basin encompasses, either wholly or partially, approximately 30 communities in western Massachusetts. Communities in the northern portion of the watershed are primarily rural and sparsely populated. More concentrated population centers including the cities of Westfield, West Springfield, Holyoke, and the town of Agawam, lie in the southern portion of the watershed.

Early development within the basin occurred along the rivers and streams on the eastern slopes of the Berkshires during the mid-1700's. The establishment of grist, saw, and paper mills and tanneries characterized early industry. However, due to the rugged terrain throughout the region, expansion of industry was limited to the southeastern portion of the watershed, with the northern communities concentrating on agricultural activities.

Holyoke, with a population of 44,678 in 1980, is the most populated community in the watershed, followed by Westfield with 36,465, West Springfield with 27,042 and Agawam with 26,271. All of the other communities with the exception of Tolland and Southfield, Connecticut, and Southampton, Massachusetts have populations under 2,000. The towns of Huntington and Chester both showed growth between 1970 and 1980. Huntington's population grew 13.2 percent to 1,804 and Chester's population grew 9.6 percent to 1,123. Overall, the basin communities have continued to experience population increases with Holyoke the only community to show significant losses.

Many residents living in the northern portion of the watershed are still engaged in agricultural activities. Other residents commute to jobs in the larger population centers in the Pittsfield and Springfield-Chicopee-Holyoke (SCH) Standard Metropolitan Statistical Area (SMSA). Manufacturing is the largest employment sector in the southern portion of the watershed, although it has experienced a decline in total number employed. Sectors showing increases in employment include the services and finance, insurance, and real estate sectors.

Chester and Huntington

Population

The Littleville Dam lies in Huntington. However, the impounded area lies in Chester. As indicated earlier, populations in Chester and Huntington in 1980 were 1,123 and 1,804 respectively. Although both populations showed similar increases over 1970 populations, Chester's population between 1930 and 1980 showed more fluctuation than Huntington's with a net loss of 23.3 percent. On the other hand, Huntington's population has increased during each decade with the exception of the 1940-1950 period and has experienced a net population increase of 45.2 percent. Population data for the two communities is provided in Table C-4. The latest available population projections indicate continued growth at a modest rate.

TABLE C-4

POPULATION-CHESTER AND HUNTINGTON

Year	Chester Number	Chester Percent Change from Previous Decade	Huntington Number	Huntington Percent Change from Previous Decade
1980	1,123	9.6	1,804	13.2
1970	1,025	-11.3	1,593	14.4
1960	1,155	-10.6	1,392	10.7
1950	1,292	0.6	1,257	-6.2
1940	1,284	-12.3	1,340	7.9
1930	1,464		1,242	

Housing units in Chester totalled 510 in 1980, an increase of 28.8 percent over the 1970 total of 396. Total number of units in Huntington also showed a significant increase, although not as great, of 18.6 to 759 in 1980 from 640 in 1970.

Employment

A total of 15 establishments in Chester reported to the Division of Employment Security and indicated employment of 210 people. These employees are covered by the Massachusetts Employment Security Law. Employees of religious organizations, smaller agricultural firms, and people self-employed are not covered by this law and are therefore not included in this count. Eighty percent of the 210 workers were employed in the manufacturing sector with other employment in the government, trade, and services sectors.

Employment in Huntington in 1980 totalled 328 from the 26 establishments that reported. Approximately 75 percent of the 328 workers are employed by the State and local governments. Additional employment was noted in all other sectors with the exception of mining, but protection of the confidentiality of data from individual employers limited the revelation of a count for most sectors. Whereas, these figures provide the numbers of people employed by businesses in each community, labor force data indicates the number of residents in each community who are employed or looking for employment.

Chester's labor force averaged 465 in 1981. With 34 people unemployed, the community had an unemployment rate of 7.3 percent. Huntington's labor force of 657 fared better with an unemployment rate of 6.8 percent. These rates, however, exceeded the State's rate of 6.4 percent in 1981. Labor force data is presented in Table C-5.

TABLE C-5

AVERAGE ANNUAL EMPLOYMENT, 1981
CHESTER, HUNTINGTON, AND MASSACHUSETTS

	Chester	Huntington	Massachusetts
Labor Force	465	657	2,961,000
Employed	431	612	2,773,000
Unemployed	34	45	188,000
Unemployment Rate	7.3	6.8	6.4

Land Use

Approximately 1/3 of the land area in each of the two communities is developed. An overwhelming proportion of the land included in the developed acreage falls in the recreation category and includes significant tracts of State forest lands in each community. Of urban type uses, residential land in low density predominates.

Land surrounding the reservoir is for the most part undeveloped. Federal property totals 1,640 acres which includes 1,190 acres of forest land in addition to the lake and other project features. Some open woodland and field areas make up a small proportion of the Federal property.

The project area does satisfy some recreational needs, principally fishing. Some hunting, picnicking, boating, snowmobiling and trail bike riding also occurs.

ENVIRONMENTAL CONSEQUENCES

Topography, Geology and Climatology.

The addition of hydroelectric power to Littleville Lake is not expected to have any significant impacts on the topography, geology and climatology of the area because no change in the existing reservoir is proposed. Construction of the penstock and power house downstream of the dam would necessitate some blasting into bedrock and removal of surface materials immediately downstream of the dam. Such activities would have little effect on the natural topography and geology of the site since both were altered during dam construction.

Aquatic Ecosystem.

As described in the Main Report, two alternatives for hydropower development at Littleville Lake were proposed. Alternative "1" would use the existing water supply line as a penstock, whereas Alternative "2" would use the existing flood control outlet works. The impacts on the aquatic ecosystem would vary with each alternative. The Corps of Engineers, New England Division (CENED), performed a modeling study to delineate changes in water quality associated with each alternative and to aid in the assessment of impacts to the existing fishery. A report on this study is included in Appendix B of this document. Because Alternative "2" would effect little change to the existing water quality of the reservoir and downstream riverine habitats, it, therefore, serves as a baseline for which to compare with the changes associated with Alternative "1". These existing conditions have been described in the Main Report and in Appendix B in more detail.

Alternative "1"

Water Quality.

As indicated above, Alternative "1" involves the modification of the existing water supply line for use as a penstock to the proposed downstream power plant. This line includes a multilevel port tower which can be used to selectively withdraw water from four different elevations in the reservoir: 447, 466, 485 and 504 ft. NGVD. Based on the required flows, two or more ports would have to be opened for hydropower generation. Such withdrawal during the summer density stratification of the lake would change the water quality parameters in the reservoir as well as downstream of the dam. Selective multilevel withdrawal of a reservoir can be managed to optimize downstream water quality conditions for specific fishery management objectives (Fontane et al., 1982). Use of the Littleville water supply tower provides such an opportunity to develop a year round cold water fishery in place of the existing seasonal one. However, such a benefit would have effects on the reservoir. Water temperature changes have been outlined in the modeling study, which mainly evaluated simultaneous withdrawal from the two bottom elevations of the tower (447 and 466 ft. NGVD), although use of the top and bottom ports (elevations 447 and 504 ft. NGVD) were addressed and identified as Alternative 1A.

Impacts to the reservoir water quality. The modeled temperature profiles of Littleville Lake for Alternatives "1" and "2" are shown in Plates B-11 and B-12 of Appendix B. The profile of Alternative "2" indicates existing conditions.

Comparison of Alternatives "1" and "2" (Plates B-11 and B-12) indicate that withdrawal from the two bottom ports (Alternative 1) would generally reduce the existing density stratification of Littleville Lake during the months of July, August and September. This would remove the cooler bottom waters and promote greater vertical mixing with warmer surface waters to generally increase water temperatures. Generally, hypolimnion and metalimnion temperatures would increase as much as 15° to 20° F above the existing temperatures. Epilimnion temperatures could increase by as much as 2° F as a result of the lack of surface water removal. The depth that the epilimnion extends into the water column would also increase during August, September and October. This thicker surface layer would cool more slowly and, thereby potentially delaying autumnal isothermal conditions by two to four weeks. Simultaneous withdrawal from the top and bottom ports (Alternative "1A" of the Water Quality Study, Appendix B) would reduce the depth of the epilimnion from the Alternative "1" condition.

Increased mixing of the hypolimnion due to bottom withdrawal would generally increase the dissolved oxygen (DO) concentrations in this deepest density layer. DO levels below the epilimnion, under present conditions, are generally 5 mg/l or less and may reach as low as 1 mg/l or less near the bottom during August or September. Based on an average monthly flow of 32 cfs, it is estimated that the entire water volume below the 455 feet elevation would be exchanged in four days if a bottom port is used. This increased flushing and mixing action would generally reduce the biological and chemical oxygen demanding substances in the bottom waters so that the resulting minimum DO levels would be about 4 mg/l. Levels higher in the water column would similarly improve and range from 4-8 mg/l.

When the bottom ports are initially opened, the created currents are expected to mix the accumulated bottom sediments with the water column. Initial increases in color, iron, maganese, total and dissolved solids are anticipated. Once the reservoir is flushed, these levels would taper off over time. The level of toxic substances such as Hydrogen Sulfide (H_2S) and ammonia (NH_3) should also decrease.

Impacts to the downstream water quality. The water quality of the downstream releases from Littleville dam would also be affected by use of the water supply intake structures. Comparison of Plates B-13 through B-16 indicate that releases from the two bottom ports would generally decrease water temperature about $20^{\circ}F$, with extremes as much as $30^{\circ}F$. The curves of the wet years, 1972 and 1975, (B-14, B-15, respectively) exhibit relatively unstable temperatures compared with the dry years 1970 and 1980. The latter is the result of released flood control storage or runoff from freshets. Flows exceeding 140 cfs would be directed through the flood control gate which withdraws water from the warmer epilimnion waters at the surface. The model indicates water temperatures could increase as high as $10^{\circ}F$. for as long as one week.

Withdrawal from the top and bottom ports (Alternative "1A", Appendix B) would mix the warmer surface waters with cooler hypolimnion waters, and thereby, producing a temperature regime intermediate to Alternatives 1 and 2 (Plate B-16). The model indicated that the water temperatures in a cool dry year (1980) would increase as much as $11^{\circ}F$. over Alternative "1" during July. The slope of the temperature curve of Alternative "1A" exhibits a narrower range of values over a longer period with stream temperatures varying from 50°- 61° F from mid-June through mid-October. Temperature spikes caused by discharges during freshets would probably be less than those of Alternative "1" because the withdrawal of warmer waters.

Dissolved oxygen (DO) levels in the stream would decrease during the initial releases from the lakes hypolimnion waters. Once this water is flushed the DO levels should increase and return to higher concentrations. Over the long term it is estimated that DO levels of bottom released water would reach minimum values of about 4mg/1 during summer periods. Simultaneous withdrawal of water from the upper and lower ports would mix the bottom waters with the more oxygenated surface waters and thereby increase the DO levels of the outflow above that of the two bottom port releases. Further study could refine this strategy.

As indicated above color, iron, maganese, suspended and dissolved solids, H_2S, and NH_3 would increase in the stream upon initial release of bottom waters through the lower ports. Flushing over time would eventually decrease the concentrations of these substances in the downstream releases until the reservoir level stablizes. Mixture with epilminion waters would tend to dilute the concentration of these constituents and thus upgrade the general water quality. Because of the short residence time associated with bottom withdrawal, the long term levels are expected to remain low.

Construction impacts. Construction activities would occur only in the area just below the dam. They would involve earth moving activities, blasting into bedrock and use of heavy equipment near the stream bank. This will cause an introduction of suspended and dissolved solids into the downstream section of the river. Such increases would occur only during the construction period. Appropriate mitigation measures to minimize siltation would be implemented during this period and therefore significant impact to the downstream water quality is not anticipated. Low flows during summer would also allow for quick deposition of any suspended material a short distance downstream.

Fisheries.

Use of Alternative "1" would impact the reservoir and downstream fisheries with regard to changes in the quality of aquatic habitat and mortality induced by turbine passage.

Reservoir habitat. As indicated above, the most significant change in the reservoir aquatic habitat is the alteration of the summer temperature profiles. The model indicated a reduction in stratification associated with an increase of water temperatures at depth. Preferred/optimal growth temperatures for the three species of trout found in the Littleville Lake generally range from 50-65°F (Carlander, 1969; Bell, 1973). The state's criteria, set by the Massachusetts Division of Fisheries and Wildlife (MDFW) has established an upper temperature limit of 68°F for a cold water fishery. Comparison of the modeled reservoir temperature profiles in Plates B-11 and B-12 indicate that the average depth of the 68°F isotherm for Alternative "1" would exceed existing depths (Alternative "2") by about five feet in July, 15 feet in August and 13 feet in September. This represents a loss in volume of available cold water fishery habitat, which can be quantified by the following calculation. The minimum storage for available coldwater fishery habitat in the lake can be determined by comparison of the modeled temperature profiles and the area-capacity curve (Plate A-10). Elevations of the 63°F isotherm in August under existing conditions (Alternative "2") would range in elevations from 503-509, NGVD. Assuming that trout would not go below 55 feet, the available water space below the mean 68°F isotherm (506 feet) would be about 5800 acre-feet. The August 68° F isotherm of Alternative "1" would range from 490 to 495 ft NGVD. This translates to about 3500 acre-feet of available habitat. This represents a net loss of about 2300 acre-feet of cold water habitat. Withdrawal from the top and bottom ports in August (Alternative 1A, Appendix B) would reduce this loss about 600 acre-feet for the study year 1980.

Hypolimnion withdrawal would benefit the reservoir fishery by increasing the dissolved oxygen (DO) levels below the epilimnion. Cold water species such as trout generally prefer DO levels in excess of 5 or 6 mg/1. Currently, the DO levels during summer decrease to less than 5 mg/1 at depths below the epilimnion. The improvement may partially offset the loss of cold water habitat due to overall temperature increases. However the DO saturation levels in water at higher temperatures would be decreased.

The increase in dissolved and suspended solids, manganese, iron, H_2S and ammonia in the bottom waters may reach instantaneous concentrations high enough to be stressful or toxic to certain species of aquatic life. These increases would only be temporary and would be diluted by mixing with upper level "cleaner" waters. Despite mixing, the highest concentrations would occur near the bottom where little aquatic life is found. Continuous flushing would decrease these levels over the long term.

Under the current stocking program, Alternative "1" would have little effect on the cold water reservoir fishery because most trout would have been harvested or passed downstream by the time the warm water temperatures become established. Also, little impact is expected to the lake warm water fishery. The increased flushing would decrease reservoir nutrients over the long term. Often, this can lead to a loss in general lake productivity which, in turn, can impact a supported warm water fishery. However, this loss may be offset by the general increase in water temperature which may maintain lake productivity near its present levels.

Under the proposed "run of the river" operational mode, daily power pool fluctuations would not exceed 0.5 foot. Such small fluctuations would have little impact on the reservoir fishery. Since Littleville Lake would continue to be used for flood control and water supply purposes, the pool fluctuations associated with these uses would continue to occur. Associated impacts to the reservoir fishery from these latter uses are beyond the scope of this report and have been addressed in the Environmental Assessment of the Operation and Maintenance of Littleville Lake (CE, 1973). The addition of daily fluctuations associated with hydropower generation would not significantly change these impacts.

Downstream habitat. Hypolimnion withdrawals would have the beneficial impact of creating a downstream year round cold water fishery in place of the existing seasonal one. Plates B-13 through B-16 indicates the 68°F temperature criterion would only be rarely exceeded during the summer for short periods. This would provide a more suitable temperature environment for cold water species and would probably exclude many warm water species at least in the upper reaches of the one mile downstream area.

The above described temperature variations, as a result of flood control releases or freshets, would vary as great as 10°F for a period of one week. The differences would temporarily impact the quality of the cold water habitat. This could cause thermal stress to resident species but probably would not be lethal to most. Upper lethal temperature limits of adult rainbow, brown and brook trouts range from the mid-70's to mid-80's°F (Carlander, 1969). Threinan (1958) found that rainbow trout acclimated to 50°-53°F tolerated a temperature shock of a 14°F increase but did not survive a shock of a 20°F increase. Because the anticipated temperature increases would not generally exceed 10°F, rainbow and brown trout would be expected to survive the shock. Brook trout are generally less tolerant and may become more stressed and potentially they could perish. Such instances would be dependent upon climatological and hydrological conditions and this would be sporadic in frequency. Also, the most frequent occurrence and surface releases would be expected during the spring months when the temperature differences would probably be minor.

The dissolved oxygen levels in the released downstream waters would initially be low because of the increased oxygen demanding substances in the reservoir bottom waters. Fish, which reside immediately downstream of the outlet, would be stressed or could perish from these releases. Once the bottom waters are flushed, these substances would be reduced and an increase in DO would occur in the reservoir's deeper waters and, hence, the released water. Releases during summer months, however, may get as low as 4 mg/1 if the two bottom ports are used. This could cause stress to cold water species especially during low flows. This impact would decrease in severity as the water is oxygenated downstream. Use of the bottom and top ports could mix the cooler bottom waters with the warmer oxygenated surface waters to effectively increase the DO of the release water.

The present modeling study indicates that downstream habitat improvement is feasible. It is evident that further study is needed to optimize the downstream temperatues and DO regimes. A selective withdrawal strategy from the different tower ports can be developed to improve the downstream conditions and reduce any associated impacts to the reservoir fishery habitat (Fontane et al., 1982). For example, the model projected that withdrawal from the top and bottom ports for the study year, 1980, reduced the depth of the 68°F isotherm in the reservoir which resulted in a downstream water temperature intermediate between Alternatives "1" and "2".

Downstream dissolved oxygen levels would probably follow a similar pattern. This alternative would also reduce the downstream temperature variations association with freshets. Augmentation of downstream low flow can also be integrated into future modeling studies to determine if the cold water habitat could be maintained during summer low flows. Further study would be coordinated with the MDFW to modify fishery management objectives for enhancement of downstream fishing opportunities. The downstream fisheries would also be affected by the temporary siltation caused by construction activities described in the previous section. Fish are highly mobile and if stressed would probably avoid the affected areas. Less mobile forms such as sessile invertebrates may not swim extended periods of turbidity. This temporary loss of benthic forage would not be significant during the construction period. Mitigation measures would be implemented to reduce sedimentation as much as possible. Work during summer low flows would also mitigate this impact because suspended materials would be carried only a short distance downstream.

Because the plant would be operated strictly as a "run of the river" project, no variations of downstream flows are expected from the operation of hydropower. When the flows are less than 82 cfs, the turbine will be shut down. During this time water would continue to be released from the multilevel port tower. This would be probably occur most, if not all, of the summer months. Flow variations from flood control operations and potential water supply use would occur as usual. The impacts to the downstream supply use would occur as usual. The impacts to the downstream fishery associated with these variations are beyond the scope of this study and have been addressed in the Environmental Assessment for the Operation and Maintenance of the Littleville Lake (CE, 1973).

The discharge channel for the flood control gate (Plate 6) would only be used for discharge of flows in excess of 140 cfs. This area would be dewatered for most of the summer months. The channel is steeply graded and, therefore, does not provide suitable fish holding habitat. Its temporary loss would not be significant. This area also would be subject to dewatering if the City of Springfield chooses to use its water supply from the lake.

Turbine Mortality. Many fish residing and/or stocked in the reservoir, that are not harvested by anglers, would find their way downstream through the outlet works. Fish would have a tendancy to align themselves against the currents created by withdrawal in the reservoir ports. As fish approach the portals, current velocities (11 ft/sec) would probably exceed the swimming ability of most species and therefore would carry the fish through the portal or impinge the fish against the trashrack. The majority of fish would be expected to pass through to the penstock turbine and tailwaters. The impacts associated with fish passing through hydroelectric turbines has been reviewed by Turbule *et al*. (1981), Ruggles *et al*. (1981) and Gloss (1982). Fish may be stressed, injured or killed by pressure changes, shearing forces or cavitation associated with the hydraulics of turbine passage, or by physical contact with the blades, gates, etc. or any combination (Bell, 1973). Mortality may be direct or indirect. Direct mortality can be instantaneous or delayed. Indirect mortalities would occur by increasing the fish's susceptibility to disease or predation after entrainment. The impact can vary with the species and size of the fish, turbine type, amount of head, runner speed, efficiency and a number of other operational characteristics. Mortalities would therefore be site specific. Studies on salmonid mortality associated with Francis turbine units have been done on the west coast and may be applicable to this project. In lieu of on-site studies, the best available information indicates that Francis units have a live fish passage efficiency of 85% or higher (Bell, 1973). Gloss (1982) and Knapp (1982) have concurred that this estimate is valid under optimal operating/design conditions which can be assumed for this project. Thus under worst case conditions about 15% of the fish that pass through the turbines would probably not survive. This value could be exceeded when the turbine is operating under less than full efficiency (Bell, 1973; Gloss, 1982) when flows decrease to the lower limit of operation (about 82 cfs). Other operational modes may be considered at later stages of planning/design to increase the turbine efficiency.

The potential use of various screens to prevent entrainment of reservoir fish was investigated and determined not to be feasible based on engineering and/or economic criteria (see 2 August 1982 letter to the Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles, Appendix D). Therefore, the expected mortality is unavoidable. Because the significant fishery in the reservoir is a stocked population, the impact is considered a recreational impact rather than an ecological one. This is discussed below in the "Recreational Considerations" Section.

Alternative "2"

Water Quality.

Alternative "2" would make use of the existing flood control outlet to deliver water to a constructed downstream penstock and power house. Water would be withdrawn at the 518 ft. elevation, NGVD, which occurs at the surface of the target pool. Thus the reservoir and downstream water quality, in terms of temperature, dissolved oxygen (DO) and other chemical parameters would not deviate from existing conditions. The thermal stratification described above and in Appendix B (Plates B-11, B-12, Alternative 2) would occur as usual with minor variations due to climatical and hydrological conditions. No change in the seasonal dissolved oxygen profile is expected due to the lack of mixing. The dissolved and suspended solids, iron, manganese, and other chemical parameters would not change in the short or long term.

The downstream water quality would also remain as it has in the past. Water temperatures approaching or exceeding 80°F (Plates B-13 through B-16) would occur for most of the summer period. Lower DO saturation levels would be associated with the warmer water temperatures.

The proposed construction activities would increase dissolved and suspended solids in the downstream waters as described in Alternative "1". The longer penstock would require a longer construction period, which would temporarily degrade the downstream water quality for a longer period than would occur for Alternative "1". Mitigation measures to control siltation would be implemented to reduce this impact.

Fisheries.

Implementation of Alternative "2" would have little impact on the existing reservoir and downstream fishery habitats. There would be no change in the depth of the 68°F isotherm in the reservoir. The lack of D.O. at depth during summer continues to reduce the value of the reservoir as a cold water fishery habitat. However, most of the presently stocked populations are either harvested by anglers or are passed downstream before the summer stratification occurs and, therefore, may be of little consequence to the present stocking levels.

With no change in the existing downstream water temperature regime, the cold water would remain seasonal. The cold water temperature criterion would be continued to be exceeded 62-83 percent of the time during the summer months.

Reservoir pool fluctuations and downstream flow variations would also occur as described in Alternative "1". Little impact is expected from each variation under the present "run of the river operation." The temperature changes due to flood control releases or freshets would not occur as described in Alternative "1" because the withdrawn water is the same temperature as the overflow. Also, the discharge channel would dewater when flows are less than 156 cfs.

The turbine mortality described in Alternative "1" would be expected to occur with this alternative.

Terrestrial Ecosystem

Construction of the penstock and powerhouse downstream of the dam would involve the disturbance of the grassy habitat that was created during the dam's construction. Once constructed a small portion of this habitat would be permanently replaced by new structures. This loss of habitat is small and is not considered to be significant.

Because the existing reservoir pool elevation would not be changed, use of either Alternative "1" or "2" would have little or no impact on the shoreline terrestrial habitat or biota. As indicated above, hydropower operation would total daily fluctuation of 0.5 feet or less and therefore should not cause any significant impacts.

Pool fluctuations due to flood storage or future use of the water supply would continue to potentially occur. The associated impacts of these uses on the terrestrial resources have been addressed in the Environmental Assessment for the Operation and Maintenance of Littleville Lake (CE, 1973).

Recreational Considerations

All of the alternative plans for development of hydropower at Littleville Lake call for keeping the lake level at the present flow elevation of 518 feet NGVD with no or minimal pool fluctuations and no downstream flow changes in the river. Consequently, the project would be operated as at present, as far as flows entering the lake and discharged downstream are concerned. This "run of the river" operation would have little or no effect on the general recreational use of the lake.

The impacts to the fishery associated with implementation of each alternative were discussed above. Alternative 1 could develop a downstream year round cold water fishery habitat. This could allow the State to manage the one mile stretch as a tailwater fishery and would increase the opportunities for quality stream fishing in the region. This increased fishing opportunity would, however, be contingent on future discussions with the State, local land owners and other local interests to provide increased access to the area. As a matter of current Federal policy, no project funds can be used to purchase land or easements for access. The total cost would have to be borne by local interests. However, the Corps would cooperate to make use of its own land in conjunction with other land owners. Development of the tailwater fishery would reduce available cold water storage in the lake during summer. Despite this loss, no adverse impacts are anticipated on the current fishing opportunities in the reservoir.

Implementation of Alternative "2" would not have any significant effect on the existing project fishery habitats. The area downstream would continue as a seasonal cold water fishery offering little opportunity during the summer months.

As mentioned above, both alternatives would involve losses on fish due to passage through the turbines. Best estimates indicate that 15 percent of the fish stocked in reservoir under worst case analysis would not be available to downstream anglers. Measures to prevent entrainment were investigated at the request of State and Federal Fish and Wildlife agencies. As indicated in the 2 September 1982 Corps of Engineers letter to the MDFWRV, passive and travelling screening methods were determined not to be feasible based on engineering and/or economic criteria. Thus based on current project funding, the mortalities associated with turbine passage is unavoidable. The Corps proposed in the above stated letter that these losses could be compensated by appropriate annual increases in stocking levels at project expense. Further discussion with the State would be required to outline details of the increased stocking effort.

The impacts of flood control storage and water supply use of Littleville recreational use of the reservoir have been addressed in the Environmental Assessment of the Operation and Maintenance of Littleville Lake (CE, 1973).

Archaeological/Historic Considerations

Modifications to the dam are not expected to affect archaeological or historic resources, as the immediate vicinity of the dam was heavily disturbed at the time of construction.

Maintenance of a hydropower pool at 518 feet NGVD is not expected to affect significant archaeological or historic resources, as there will be no modification to present pool level. The area now inundated by the permanent pool formerly contained several historic period sites and had considerable prehistoric potential, but its clearing and subsequent inundation have obliterated any sites below 518 feet NGVD.

Socioeconomic Considerations

Long term effects

Socioeconomic concerns directed toward the development of hydropower capabilities at the Littleville Dam include potential effects on current flood control and water supply capabilities. Since the lake is also maintained to enhance public recreational use of the area as well as for water supply, effects on opportunities for fishing and boating would be an additional concern.

However, development of hydropower at Littleville would not interfere with the present project purposes. Water supply needs would take priority over hydropower generation and therefore no hydropower generation would occur during water supply operations. It could be possible to generate hydropower during flood control operations if the discharge downstream exceeds the minimum flow requirement of the turbine. If the minimum flow is not available, hydropower generation will not occur until the flood storage is released. Basically, hydropower development at Littleville would be a run-of-river operation.

Short term effects

In addition to any long term consequences resulting from project implementation there would also be some construction related impacts. These would include the movement of trucks, materials, and other equipment into the project area. There would be an increase in air and noise pollution levels during the construction period. These impacts would not be significant since they would be temporary and the construction site is a fairly isolated locale.

No Action Alternative

The "no action alternative" assumes that Littleville Lake would not be developed for hydropower. This will have no effect on the geological, aquatic, terrestrial, recreational or cultural resources of the project area.

Without the proposed downstream habitat improvement, the cold water fishery would remain seasonal. The no action scenario would have no significant impacts on the area's socioeconomic characteristics. The area would continue to utilize current energy sources for electricity generation, and the reservoir site would continue to offer its flood control, water supply and recreational features unaltered from what they are presently. The choice of no action over an "action" scenario would eliminate the short term impacts, (increased temporary employment, rise in noise and air pollution levels, etc.) that are typically associated with construction.

COORDINATION

Public Involvement

This project is being planned by the Corps of Engineers in coordination with other Federal, State and local concerns. With regard to environmental matters, a number of agencies and individuals have been consulted or have supplied this office with information for development of this study. Pertinent written correspondence may be found in Appendix of this report.

Mr. Steve Chmura, Commissioner, Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles.
Mr. Joseph Bergin, Massachusetts Division of Fisheries and Wildlife.
Mr. David Halliwell, Massachusetts Division of Fisheries and Wildlife.
Mr. John Feingold, Massachusetts National Heritage Program.
Mr. Richard Foster, Massachusetts Audubon Society.
Mr. Edward Taft, Stone and Webster Engineering.
Mr. Joseph Berry, B & P Industries.
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Mr. William Knapp, U.S. Fish and Wildlife Service.
Mr. Fred Benson, U.S. Fish and Wildlife Service.
Mr. Marcus Kempe, Metropolitan District Commission.
Mr. Henry Besford, Metropolitan District Commission, Quabbin Reservoir.
Ms. Patricia Weslowski, Massachusetts Historical Commission.

This draft report is being issued to the following agencies for review. Comments on this document will be considered in preparation of the final report.

Massachusetts Historical Commission
Office of Federal Activities, U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
Office of Environmental Project Review, Department of the Interior
Department of HHS
Massachusetts Division of Fisheries and Wildlife
Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles
U.S. Department of Interior, National Park Service
Department of Energy, Region I
Regional Environmental Clearance Officer, Department of HUD
Massachusetts Audubon Society
Massachusetts State Clearing House
Massachusetts PIRG
Connecticut River Watershed Council
Federal Power Commission
HQDA (DAEN-CWP-E)
National Wildlife Federation
Environmental Protection Agency

Compliance with Environmental Protection Statutes

1. Archaeological and Historic Preservation Act, as amended, 16 U.S.C. 469 et seq. *N/A

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq. Review of this Assessment will constitute compliance with this Act.

3. Clean Water Act (Federal Water Pollution Control Act), as amended, 33 U.S.C. 1251 et seq. This work is allowed under a nationwide permit authorized by Title 33 Code Federal Regulations Part 330.5 (a)(17) as published in the 22 July 1982 Federal Register. Review of this Assessment will constitute continuing compliance with this Act.

4. Coastal Zone Management Act of 1972, as amended, 16 U.S.C. 1451 et seq. N/A

5. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq. The U.S. Fish & Wildlife Service has determined that no Federally listed endangered species occur in the project area. Review of this Assessment will determine if this Act is being complied with.

6. Estuary Protection Act, 16 U.S.C. 1221 et seq. N/A

7. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq. Review of this Assessment by the Department of Interior will constitute compliance with this Act.

8. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq. Review of this Assessment will constitute continuing compliance with this Act.

9. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq. Review of this Assessment by the Department of Interior will constitute compliance with this Act.

10. Marine Protection, Research, and Sanctuaries Act of 1972, as amended, 33 U.S.C. 1401 et seq. N/A

11. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq. Review of this Assessment will constitute continuing compliance with this Act.

12. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 432 et seq. Review of this Assessment will constitute continuing compliance with this Act.

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*N/A - Not Applicable

13. Rivers and Harbors Appropriation Act of 1899, as amended, 33 U.S.C. 401 _et seq._ N/A

14. Watershed Protection and Flood Prevention Act, as amended, 16 U.S.C. 1001 _et seq._ N/A

15. Wild and Scenic Rivers Act, as amended 16 U.S.C. 1271 _et seq._ N/A

Ruggles, C.P., N.H. Collins, and R.H. Flicke. 1981. Fish Passage through Hydraulic Turbines. Paper presented to the Spring Meeting - Canadian Electrical Association, Toronto. 30pp.

Threinen, C.W. 1958. Cause of Mortality of a Midsummer Plant of Rainbow Trout in a Southern Wisconsin Lake, with Notes on Acclimation and Lethal Temperatures. Progressive Fish Culturist 20:27.

Turbak, S.C., D.R. Reichle, and C.R. Shriner. 1981. Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development IV: Fish Mortality Resulting from Turbine Passage. Environmental Sciences Division, Publication No. 1597, Oak Ridge, National Laboratory, Oak Ridge, TN. 111pp.